IMPROVING THE DISPLAY OF MARINE RADAR RETURNS FROM FIRST YEAR SEA ICE

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The Centre for Cold Ocean Resources Engineering (C-CORE) was established at Memorial University of Newfoundland in 1975. Its initial funding was provided by the Devonian Group of Charitable Foundations in Calgary, Alberta. Ongoing funding now comes from government and industry.

The Centre's mandate is to undertake research that will assist the safe and orderly development of Canada's resources in cold and ice frequented oceans.

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ABSTRACT

A scan converter display was used to record land based marine radar returns from first year sea ice. The scan converter system was chosen because of dynamic range considerations, real time capability and output format for video display storage purposes.

The system was used to study the smaller variations in the radar returns from first year sea ice, normally not readily distinguished on a marine radar Plan Position Indicator (PPI).

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TABLE OF CONTENTS

	Page
ABSTRACT	i
ACKNOWLEDGEMENTS	ii
TABLE OF CONTENTS	iii
LIST OF FIGURES	v
1. INTRODUCTION	1
2. CONVENTIONAL MARINE RADAR FOR ICE REMOTE SENSING	3
2.1 The Plan Position Indicator Display: Practical Considerations	4
2.2 Signal Processing	5
3. SYSTEM DESCRIPTION	7
3.1 The Requirement	7
3.2 Engineering Options	8
3.3 Interfacing to the Radar	9
3.4 Technical Description	10
3.5 The Radar Video	20
3.6 Advantages and Disadvantages of Display	20
3.7 Small Signal Response of Scan Converter	23
4. FIELD WORK	31
4.1 Cape Spear, Nfld. - sea clutter and targets	31
4.2 Cape Norman, Nfld. - range of detectability/ moving ice	34
4.3 Tarsiut Island, Beaufort Sea, N.W.T. - ridge returns consolidated ice	38
5. PROCESSING DISPLAY IMAGES	41
5.1 Scan integration	41
5.2 Post Processing Techniques	42
6. DISCUSSION OF RESULTS AND OBSERVATIONS	45
6.1 Discussion	45
7. CONCLUSIONS	59
REFERENCES	60
APPENDICES A - ELECTRONIC DRAWINGS	61
B - MANUFACTURER'S SPECIFICATIONS	67
C - SIGNAL GLOSSARY	71
D - HARDWARE COSTS	75

LIST OF FIGURES

PAGE

Figure 1 - System Logic Block Diagram ---------- 12

Figure 2 - Timing Diagram ---------- 14

Figure 3 - Calibration of Scan Converter. Signal Input Waveforms ---------- 26

Figure 4 - Scan Converter Response Video Output Waveform ---------- 26

Figure 5 - Scan Converter Response Video putput Waveform ---------- 27

Figure 6 - Calibration of Scan Converter. Signal input Waveforms ---------- 28

Figure 7 - Scan Converter Response Video output waveform 29

Figure 8 - Scan Converter Response Video output waveform 29

Figure 9 - Site Photo, Cape Spear, Nfld. ---------- 30

Figure 10 - Map, Cape Spear, Nfld. ---------- 30

Figure 11 - Scan Converter Display, Cape Spear --------- 32

Figure 12 - Effect of Photographic Averaging on Sea Clutter ---------- 33

Figure 13 - Map, Cape Norman, Nfld. ---------- 35

Figure 14 - Site Photo, Cape Norman ---------- 36

Figure 15 - Site Photo, Cape Norman ---------- 36

Figure 16 - Inside VTS Unit ---------- 37

Figure 17 - Close up of Sea Ice Near Cape Norman ------- 37

Figure 18 - Map, Tarsiut Island, Beaufort, N.W.T. ------ 39

Figure 19 - Aerial Site Photo, Tarsiut Island ---------- 40

Figure 20 - Scan Converter display of first year sea ice returns, Cape Norman ---------- 44

Figure 21 - Integration of a sequence of 26 scan converter display images recorded at Cape Norman ----- 44

PAGE

Figure 22 - Intensity distributions of Figures 20 and 21 along two radial vectors ---------- 46-47

Figure 23 - Two scan converter display images of first year sea ice returns taken approximately 19 seconds apart from the Strait of Belle Isle- 50

Figure 24 - Successive intervals of data from the Strait of Belle Isle, photographically averaged --- 50-51

Figure 25 - Scan converter display of first year sea ice features, Tarsiut Island, Beaufort, N.W.T. - 52

Figure 26 - Radar display from Tarsiut Island 12 nautical mile range ---------- 52

Figure 27 - Integration of five scan converter images recorded at Tarsiut Island ---------- 53

Figure 28 - Integration of ten scan converter images recorded at Tarsiut Island ---------- 53

Figure 29 - Integration of twenty scan converter images recorded at Tarsiut Island ---------- 54

Figure 30 - Integration of thirty scan converter images recorded at Tarsiut Island ---------- 54

Figure 31 - Integration of thirty-eight scan converter images recorded at Tarsiut Island ---------- 55

Figure 32 - Five different spatial filtering techniques applied to the image of Figure 31 ---------- 56-57

Figure 33 - Spatial filtering of the image in Figure 25 58

1. INTRODUCTION

Today marine radar can be found on most marine vessels, on fixed offshore structures, and sometimes as a coastal installation. The most common version is X-band (8 to 12 GHz). Initially used to monitor the position of an approaching vessel, and for coastal navigation the merit of marine radar was most apparent under poor visibility conditions. Since its inception the use of marine radar has expanded to include the detection of icebergs, multi year and first year sea ice (FYSI).

As with any remote sensing device the display of information requires interpretation and an understanding of the data collection process. Particularly with icebergs and FYSI the detection process is much more variable than with ships. Consequently the interpretation of the marine radar display is more difficult.

Two avenues are open to improve the usefulness of marine radar for monitoring FYSI. The first is the total redesign of the radar hardware including the display, optimizing for the response to FYSI. This work is already ongoing at McMaster University.

The second avenue is to look for short term improvements to existing commercial systems. This will not result in a perfect detection system, but could substantially improve the amount of extractable information from existing systems.

C-CORE saw an opportunity to work at the display end of the system to acquire more useable information by increasing the dynamic range of the display. It was expected that this increase

would magnify small differences in the marine radar video and therefore make it easier to interpret the information. A steady display was used so that patterns formed by small differences in the video could be identified more easily. The system was expected to increase the display's dynamic range and also to store the video in a format for further signal processing as required.

This project included the engineering and testing of a radar interface and display system to extract the video, display the result as previously described, and put it into a convenient format for storage. Data was recorded at two different locations overlooking first year sea ice.

This report describes the display system and interface used for the data collection in Section 3. The field work is described in Section 4. Image processing techniques applied to the collected data are described in Section 5. The results of display performance and further image processing of the data collected are described in Section 6. Conclusions based on the results are listed in Section 7. The report begins with a brief description of the typical marine radar display and the common signal processing techniques used in such a system.

2. CONVENTIONAL MARINE RADAR FOR REMOTE SENSING ICE CONDITIONS

Marine radar, which is defined for the purpose of this work as an X-band or S-band (2-4 GH_z) incoherent narrow beam system, is used on ships to detect and identify obstacles in a ships path, as well as to establish safe areas for navigation remotely. This application clearly includes the remote sensing of floating sea ice. It is often placed on coastlines and drill islands, to monitor local ice movements and changing ice conditions.

When visibility is limited, marine radar is often relied upon to identify pack ice and related hazardous features. The operator observes the Plan Position Indicator (PPI) of the radar and monitors "blips" from scan to scan. However, the small dynamic range (number of distinguishable intensity levels available) of the display does not permit extensive interpretation. It establishes the target's position and often only the extent of one dimension. The operator uses the gradual change in the target's position and/or a process of pattern recognition to interpret the display. If a consistent pattern shows up on every scan, there is a fair chance that it will be identified. If it shows up only periodically, the operator may never make a positive identification.

The operator can often make a mental picture of the surroundings based on the PPI display. If the blips vary from scan to scan the picture will be vague.

2.1 The Plan Position Indicator, Display: Practical Considerations

The Plan Position Indicator (PPI) is the most common marine radar display. Information is continuously written in polar coordinate format onto a phosphor screen, following the azimuthal position of the radar's antenna. The typical contrast ratio (i.e., dynamic range) of such a display is in the order of 10dB (Skolnik, 1980) under ideal viewing conditions. Unscreened ambient light would reduce this ratio. The contrast ratio (CR) is given (Sherr, 1970) for two different luminances, as

$$C_R = B_{max}/B_{min},$$

where we shall take

B_{max} = luminance of the object, and

B_{min} = luminance of the surrounding area.

Then the PPI's maximum C_R has a numerical value of the order of 10 based on the previous figure quoted in dB.

The PPI display allows information to be displayed in real time. Consistent targets can be tracked from scan to scan, but there is no means of displaying the entire scan uniformly without regard to azimuths. Typical antenna rotation times of two to three seconds and a persistence (to 10% intensity) of 0.15 seconds for P-39 phosphor (Bell, 1970) result in a display whose blips have lost up to 99% of their original intensity just prior to being rewritten. The phosphor is updated each scan. If targets did not fade, sections of the screen would eventually become saturated). The non-uniform display hinders two aspects of real time interpretation;

i) intensity comparisons of targets at different azimuths,

ii) identifying a geometrical shape by following constant intensity boundaries.

If the dynamic range of the video signal is greater than 10dB, the phosphor display will compress the dynamic range of the available information. If such is the case, small signal differences outside the display's dynamic range will not be visible, or will be merged into the stronger signals.

2.2 Signal Processing

Real time signal processing is a standard feature of marine radar. Gain control and filtering are used to suppress unwanted video signals (commonly referred to as clutter) from saturating the PPI. The common techniques in use are described.

2.2.1 Processing Techniques (Real Time)

Sensitivity Time Control (STC):

Sea clutter is removed by the application of "Swept Gain" to the radar's normally flat gain versus range curve. STC initially depresses the gain at range zero, allowing the gain to climb back to its normal value as the range increases. Swept Gain therefore has a greater effect at shorter ranges. On a Decca 914A X-band radar this effect is negligible beyond 8 n. miles (Sec. 2, Chap. 3, Decca Manual).

Although quite effective in reducing sea clutter, the Swept Gain can also cause small targets to be lost at short range (i.e. the gain is dropped to stop sea clutter from saturating the PPI.

This reduces the strength of any target in the clutter zone by the same percentage as the clutter is reduced. If the clutter is stronger than the target, then the target will probably be lost before the clutter can be removed.

Fast Time Constant (FTC):

The backscatter from heavy precipitation, can also saturate the PPI. Weather clutter can be removed by applying a high pass filter to the video. This is equivalent to differentiation (see Skolnik, 1980, p. 507). This does not, however, permit sub-clutter visibility. FTC only removes the saturating effect of weather clutter obscuring a target that is stronger than the clutter signal. Unlike swept gain, FTC acts equally at all ranges.

3. SYSTEM DESCRIPTION

The system was designed to be a real time display application for marine radar. It stores the full range of the radar video signal for one complete radar sweep (i.e. one antenna rotation) onto a 64 grey tone "scan converter" (manufacturers specifications), and then outputs in raster scan format to a black and white television monitor for display. The main advantage of this display is a dynamic range greater than that of the PPI.

Section 3.1 illustrates the perceived system requirement and Section 3.2 lists the options considered before a configuration was chosen. Section 3.3 discusses interfacing considerations. Section 3.4 describes the interface which samples the necessary radar signals, the conversion of the radar's polar coordinates to cartesian and the storage and display of radar video for one radar scan. Sections 3.5, 3.6, 3.7 discuss other points of consideration relevant to the operation of the display system.

3.1 The Requirement

The basic objective was to expand the range of grey scale display for a typical marine radar. This large dynamic range would "enhance" the available information, permitting interpretation of small signal difference in the radar video. Storage of the data for future analysis was also considered necessary.

3.2 Engineering Options

Before the configuration was chosen, the question posed was how an increase in display dynamic range should be effected. An internal engineering report indicated that there were a number of possible methods.

Option A:

The radar video could be stored on magnetic tape and processed at a later date. This method is expensive, since it requires a considerable investment in equipment. Also the display does not provide information in real time.

Option B:

An oscilliscope (with a high dynamic range phosphor) in x, y, z format could be used to record the radar video in Plan Position Indicator (PPI) format, and then photograph the display. The photograph could then be submitted for image analysis at Memorial University.

Option C:

A scan converter could be used to store the radar video in PPI format. The output could then be fed to a high contrast black and white monitor. This assumes the scan converter has sufficient dynamic range; the typical black and white monitor easily exceeds the necessary dynamic range required. This method would provide information in very close to real time, and the output could be stored on video tape, a comparatively inexpensive process.

Of the three options, Option C, utilizing the scan converter, seemed most cost effective. It was the closest to

real time, cost less than $10,000, was available with sufficient dynamic range and the output could be stored easily.

The particular scan converter used is capable of separating radar video into 64 grey levels. It was used in a configuration to display an entire radar scan steadily and simultaneously. This was considered necessary if patterns formed by small shade differences were to be identified. (i.e. the operator might need time to locate a subtle pattern).

3.3 Interfacing to the Radar

The PPI format of the radar had to be duplicated to transfer the radar video to the scan converter efficiently. This required a system to encode the polar coordinates (r, θ) of the electron beam writing across the PPI display instantaneously, where "r" is the radial distance and "θ" the azimuthal bearing. The radial coordinate is easily obtained by sampling the "scan ramp", which is the radial deflection signal used in the PPI writing process. "θ" however, does not exist in the form of a single signal in the radar and therefore had to be generated by monitoring the azimuthal angle of either the rotating radar antenna, the antenna drive circuitry, or the synchronized rotating deflection yoke in the PPI display unit.

To minimize engineering design and cost, a rotating shaft position encoder was purchased with the intent of coupling this device to the rotary motion of the PPI deflection yoke. It later became apparent, however, that because of space limitations it would be difficult to couple an extra mechanical device with the

radar's display unit. This mechanical modification would also be difficult to implement without risk of mechanical damage to radars which were only on temporary loan to C-CORE. The next best avenue open was to duplicate the display turning system for each type of radar under consideration. It was then a simple matter of paralleling the required drive signals out to the duplicate system, which in turn could drive the position encoder. Synchro-to-digital phase converters were also available at this time, but our schedule did not allow the extra engineering time required to support these design changes.

Another important consideration in interfacing with the radar was to determine what effect loading the video data line would have on data quality. To guard effectively against adverse effects, a high impedance video buffer was used to sample the unprocessed radar video (without any apparent adverse effect to the existing PPI display). This necessitated the design and construction of a wide bandwidth, high input impedance video amplifier and line driver matched to 75 ohms.

All other constraints in the system design were dictated by the input requirements of the scan converter. A complete system description follows.

3.4 Technical Description

The system can be broken down into four sections:

1 - A scan converter used for data storage and retrieval;

2 - The control logic which samples certain signals from the radar and controls the operation of the scan converter;

3 - A coordinate conversion system: The scan converter requires positional information in X-Y format. The electron beam in the PPI is directed in a polar coordinate format. A conversion is made of the instantaneous position of the beam into cartesian coordinates with the origin referenced to the centre of the PPI;

4 - A video amplifier taps the radar video and sends it to the scan converter.

3.4.1 The Scan Converter

The video storage device used for this project was the PEP 500 Lithocon Solid State Image Memory scan converter, manufactured by Princeton Electronics Products, Inc. The PEP 500 uses an electron beam to store and retrieve a time varying signal by "writing" a charge distribution across an electrostatic grid and then "reading" that distribution at a later time. This process is analogue, not digital. It is not capable of storing and retrieving information simultaneously. The scan converter is used in three separate modes, Read, Write and Erase.

In the Write mode, the scan converter's electron beam is directed by external X-Y inputs across an electrostatic storage grid. Simultaneously the grid voltage is modulated by the external voltage input of the radar video. This operation stores the video of one radar sweep.

The Erase mode is used to remove old information from the electrostatic grid prior to entering the Write mode.

During the Read mode, information is read continuously off

SYSTEM LOGIC BLOCK DIAGRAM

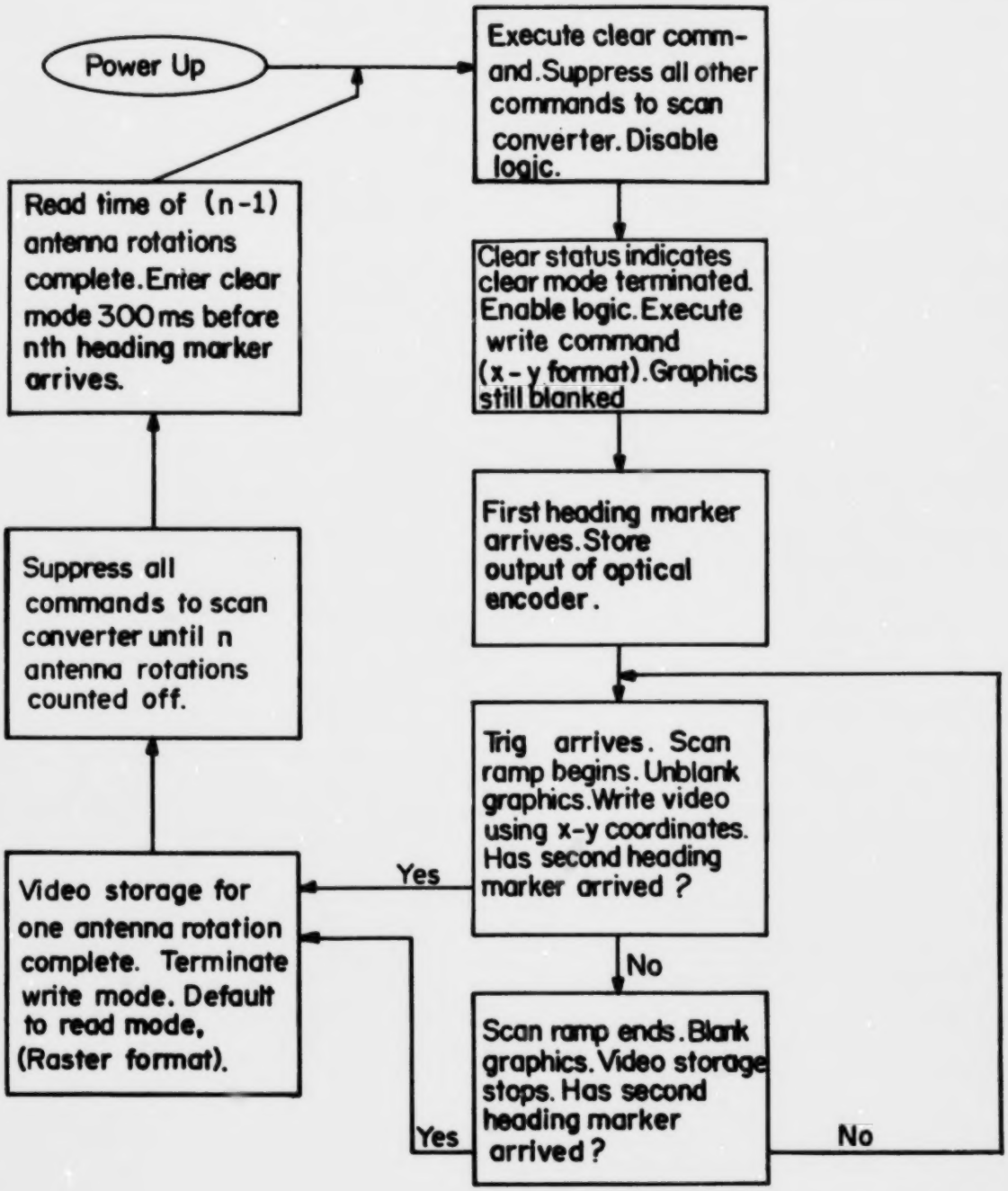

Power Up
Execute clear command. Suppress all other commands to scan converter. Disable logic.
Clear status indicates clear mode terminated. Enable logic. Execute write command (x - y format). Graphics still blanked
First heading marker arrives. Store output of optical encoder.
Trig arrives. Scan ramp begins. Unblank graphics. Write video using x-y coordinates. Has second heading marker arrived ?
Yes
No
Scan ramp ends. Blank graphics. Video storage stops. Has second heading marker arrived ?
Yes
No
Video storage for one antenna rotation complete. Terminate write mode. Default to read mode, (Raster format).
Suppress all commands to scan converter until n antenna rotations counted off.
Read time of (n-1) antenna rotations complete. Enter clear mode 300 ms before nth heading marker arrives.

Figure 1

the storage grid in raster scan format and fed out to an external standard black and white television monitor. During this mode of operation the stored radar video is displayed.

Four signal inputs (TTL) to the scan converter control its mode of operation;

i) Write Enable

ii) X-Y Enable

iii) Clear Control

iv) Graphics Unblanking

The function of each input is described in the Signal Glossary (Appendix C). Figure 1 illustrates the sequence of operation.

To initiate and maintain a "write" operation the Write Enable and X-Y Enable inputs are held high (TTL=1). The writing of information is then controlled by Graphics Unblanking (TTL=1 to write on the storage grid, TTL = 0 to blank the grid preventing storage of charge), the analogue voltages at the X and Y deflection inputs range from +2.5 to -2.5 V (nominal) as the beam is deflected across the electrostatic grid. They receive their information from the coordinate conversion system (Section 3.4.3). The video input (75 ohms, nominally 0 to 1 V, d.c. to 12 MHz) modulates the storage grid voltage, driven by the high speed video amplifier (Section 3.4.4). To initiate a "clear mode" the Clear Control is held high (TTL=1) for a minimum of 100 Us. The clear cycle once inititiated is internally controlled by the scan converter and lasts for 200 ms (nominal). During the clear cycle the scan converter generates a clear status output (TTL=1).

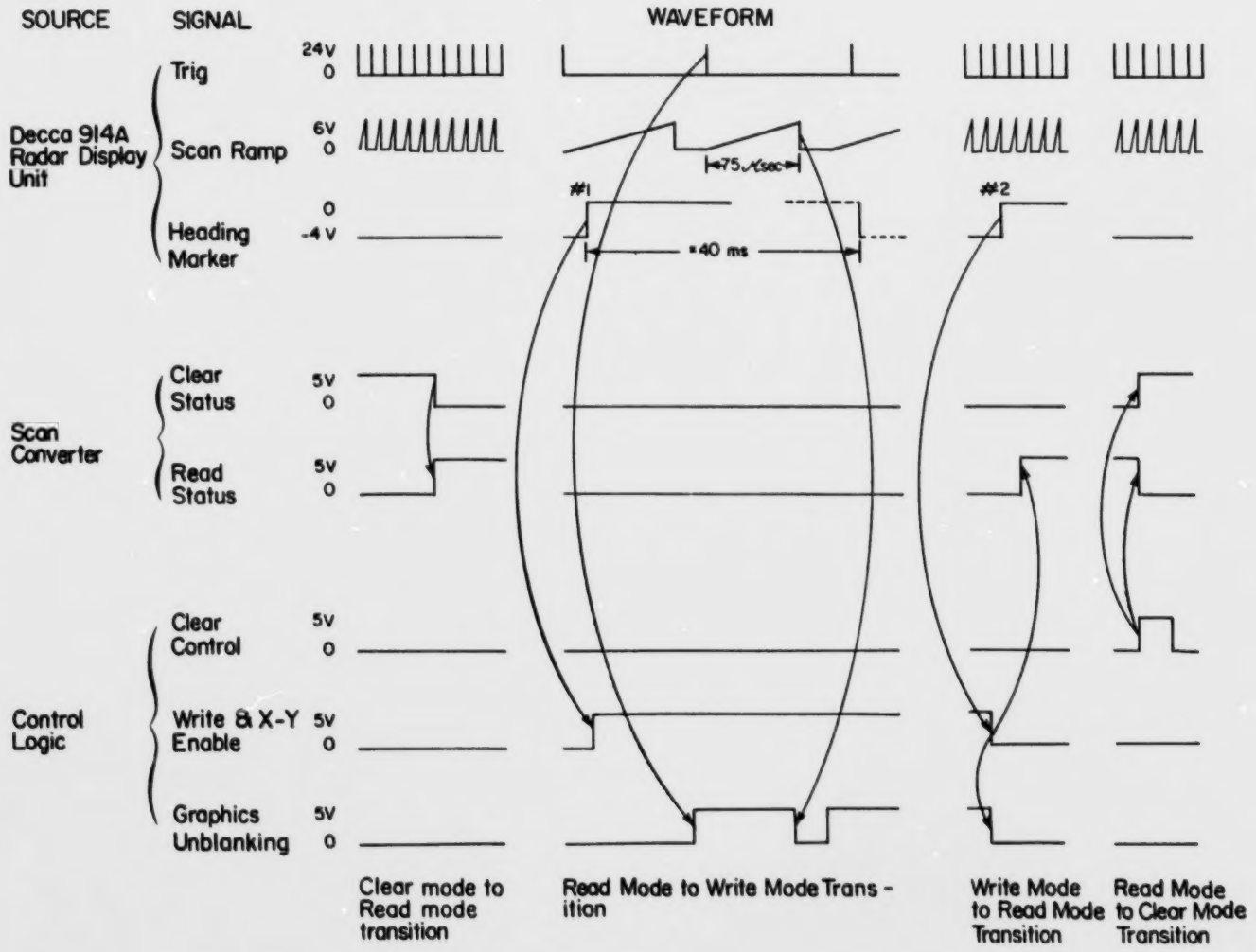


Figure 2. Timing Diagram

The Read mode is automatically entered by default if no other mode is in operation, (i.e. Write Enable = 0 and Clear Status = 0). The grid is then read off in raster format. The video output is composite, (700 mV pp, dc restored, 100 mV pedestal).

3.4.2 Control Logic Circuit Description (See Appendix A)

The following four signals are used by the control logic to generate the basic commands sent to the scan converter (see Figure 2).

i) Trigger (Trig)

ii) Scan Ramp

iii) Heading Marker

iv) Clear Status

Each of these signals is more completely described in the Signal Glossary (Appendix C). Trigger and Scan Ramp are used during the Write Mode to control the Graphics Unblanking. Trig (+24 V, 1 U sec), which always precedes the Scan Ramp, is resistively divided and ac coupled into a linear amplifier (IC 18 & R6) to provide a positive edge trigger to IC26-11. The scan ramp (0 to 6V, 75 U sec for 6 nautical mile range) is squared up and inverted by IC-31 to provide a positive edge trigger to IC-26-3. IC-26 (2 D-flip flops) is a switch ring counter feeding IC-20 and 1/2 IC21 (an exclusive OR). Therefore Graphics Unblanking= (IC 26-5) XOR (IC26-9). Once the reset has been lifted on IC-26 (i.e. Write and X-Y Enable go high) the positive leading edge of Trig initiates Graphics Unblanking (TTL=1) and

the negative falling edge of the scan ramp terminates the unblanking (TTL=0). This ensures that during the write mode radar video is only stored during the occurrences of the scan ramp.

Two successive Heading Markers (-4V to ground transition) are used to initiate and terminate the Write mode. The Write Enable command is then disabled pending the falling edge of the next Clear Status (falling edge of TTL = 1 pulse).

Once a Clear Status (TTL=1 200 ms) has reset IC 25 (a "divide by 2" feeding a latch) IC 25 waits for the output of IC 30 (monostable) which is just the debounced heading marker's positive leading edge. The first Heading Marker results in setting the Write and X-Y Enable high by toggling IC 25-5, (TTL=1). Graphics Unblanking then controls video storage as previously described. The second Heading marker toggles the "divide by 2" and sets the latch, inhibiting the Write and X-Y Enable until a Clear Status can be completed. With IC 25 latched, IC 22 (Presettable Counter) counts heading markers from the output of IC 20, starting with an initial count set by the 16 position binary switch. Until an overflow state occurs (count = 16) no action takes place. It is during this time, with the Write enable inhibited and no Clear Control output, that the scan converter defaults to the Read mode. The preset count therefore determines the display time of the stored radar sweep.

When IC 22 overflows the "carry" pulse it triggers IC 23 (a one shot) which latches IC 27, triggering IC 24 (one shot). This produces a Clear Control pulse which initiates a Clear cycle in

the scan converter. During this cycle the scan converter holds the clear status high (TTL=1) resetting ICS 25, 22, 27. Once the Clear cycle terminates the Clear Status goes low, all the appropriate counters' latches are reset and the next Write mode can be initiated.

An R-C power up circuit (R9 and C4) is used with ICS 18 and 20 to force a clear cycle when power comes up, before any other mode can be entered.

The two position switch debounced by IC 19 provides a manual override when long display times are required, by holding the output of IC 21 low.

3.4.3 Coordinate Conversion System

This system translates the polar coordinates of the PPI into Cartesian coordinates using the standard conversions;

$X = r \cos(TA)$, and

$Y = r \sin(TA)$,

where r = scale factor x instantaneous Scan Ramp voltage

TA = True Azimuthal angle (See Appendix C, Signal Glossary).

The voltages X, Y are fed to the X, Y deflection inputs of the scan converter. This directs where the raw radar video is to be written onto the electrostatic grid (see Section 3.4.1) in the same fashion as the processed radar video is written on the PPI.

This system can be broken down into three sections:

i) Vector Generator and Buffer Amplifiers

ii) Shaft Position Encoder, Bearing Amplifier and Turning Unit

iii) Absolute position synchronizer circuit Vector Generator

Circuit Description (See Appendix A, p. A-2).

A DTM 1717 Digital Vector Generator manufactured by Analog Devices performs the calculations of X and Y from a digitized angle and a scaled down Scan Ramp. The True Azimuth represented by 10 bits from the Absolute Positve Synchronizer Circuit is fed into bit inputs one through ten of the DTM1717. IC 2 (monostable) is triggered off bit 10 (LSB) to generate synthetic bit 12. The R-C time constants R8, C1 and R9, C2 are manually adjusted so that the period duty cycles of bits 12 and 11 are 50% respectively.

The Scan Ramp output voltage from the radar which is buffered using a 3140 operational amplifier (see dwg GL-D914-002-A) usually contains a d.c. pedestal and a high frequency noise component. C-5 is picked to filter out the noise component after R7 (gain adjust for ICI) has been adjusted. The gain of ICI is the "scale factor" multiplying the ramp's voltage. Adjusting R6 (d.c. bias) offsets any d.c. pedestal. The output of ICI is a clean 0 to +2.5 V ramp which feeds the input of the DTM 1717.

Shaft Position Encoder

An Absolute Position Encoder (5V80 series) manufactured by B.E.I. Electronic Inc. is used to digitize the Azimuth angle. The radar's turning unit in the PPI was duplicated in order to drive the Absolute Position Encoder without physically placing the encoder in the radar display unit. The reasons for not choosing a synchro-to-digital converter are explained in Section 3.3.

Absolute Position Synchronizer Circuit Description

The digital output of the encoder is fed to the Absolute Positive Synchronizer Circuit (See page A-3). This circuit performs three functions:

i) the output of the shaft encoder (Azimuth) is electrically debounced;

ii) the Azimuth is converted into the True Azimuth (see signal glossary);

iii) a fixed rotation bearing is continuously added to the True Azimuth.

IC's 14, 15, 16 (4 bit binary adders) add a manually preset 10 bit angle to the current Azimuth from the shaft encoder. IC's 7, 8, 9 (high speed 4 bit comparators) and IC's 3, 4 (high speed D-F/F's) form a 1 MHz debouncing circuit. The occurrence of a heading marker resets IC 10 (J-K F/F) clocking the current bits at the inputs of IC's 5, 6 (high speed D) to the outputs. This effectively stores the Azimuth plus fixed rotation angle until the next heading marker.

IC's 11, 12, 13 (4 bit full adders) which receive both the current Azimuth and the heading marker Azimuth plus fixed rotation, output the True Azimuth plus fixed rotation as required.

3.4.4 Video Amplifier

The function of this amplifier is twofold:

i) to sample the radar video without inteferring with the radar's video circuit;

ii) to apply a scale factor to the video and drive this signal into a 75 ohm load (nominal), preserving the necessary bandwidth.

IC 1 is an LH0024 high slew rate operational amplifier. IC2 is an "ultra fast" buffer amplifier, LH0063. IC 1 is configured to invert and divide by approximately 4 (for Decca Radar Bideo Input) with R2 as the gain adjust. R4 supplies the d.c. offset required. IC2 maintains the signal bandwidth while driving the 75 video input of the scan converter.

3.5 The Radar Video

The radar video contains system noise normally not displayed on the PPI to avoid saturating the phosphor. This is accomplished with a gain adjustment. But it is often difficult to determine what is only noise, and what can be a mixture of noise and real information. It was not considered desirable to start with less than 100% of the available information. For a display with sufficient dynamic range, the noise region within the radar video can still be displayed without causing saturation (i.e. there is still plenty of room for the rest of the radar video). Thus the radar video (i.e. including the noise region) was recorded either before it entered any video processing circuits or the processing circuits were deactivated when possible.

3.6 Advantages and Disadvantages of Display

With the current system configuration there are four major

disadvantages of the display.

i) There is no display of a radar sweep during the interval when radar video is being stored in the scan converter. For marine radar antenna angular velocities of 22 rpm this results in a 2 to 3 second blank display. This disadvantage could be circumvented with a more expensive double ended storage tube scan converter which would allow simultaneous reading and writing.

ii) The radar sweeps occurring during the time of display cannot be monitored on the system. For example, if the display time is equivalent to 4 radar sweeps then only one of every five radar sweeps will be displayed. The shortest display time permissable is equivalent to one antenna sweep. Only one of every two radar sweeps is be displayed; the alternate sweep is missed.

iii) The display is static. Therefore the only method of monitoring relative motion in near real time is to mark a target's initial position with a grease pencil on the TV screen and then note the change of position with the next display.

iv) The system used produced radial discontinuities (thin straight lines that extended outward from the centre of the screen every 22.5o) for radar range settings less than 6 nautical miles. This was caused by the limited slew rate of the digital vector generator being used; it could be rectified by using a higher slew rate device. This limitation on radar range setting is largely offset by the zoom capabilities of the scan converter discussed under "advantages".

There are six potential advantages of the display.

i) The scan converter allows the user to zoom in on any area of

the display and magnify it (up to a factor of 6) horizontally and vertically. Hence the minimum radar range setting noted in disadvantage iv) is effectively reduced to 1 nautical mile. The need to change radar range settings is reduced. In particular, marine radar displays will not permit the operator to magnify the display in the same fashion. For example, by changing from 6 to 3 nautical miles range on the radar an operator can magnify the first 3 nautical miles by a factor of 2; but, he cannot see the region between 3 and 6 nautical miles.

ii) The static nature of the C-CORE display lends itself to simultaneous interpretation of a complete sweep. The same cannot be said of the PPI, where the intensity distribution is a function of time and azimuth. Freezing the display is a very useful feature when the screen is filled with targets. The amount of information presented can be very complex and requires some study before the overall picture is clear.

iii) The dynamic range of the display 10 Log (64) = (18 dB) exceeds that of the PPI (10 dB). Patterns of subtle shade differences within the capability of the human eye can be identified to promote more extensive interpretation.

iv) The limited dynamic range of the PPI necessitates signal processing to avoid having clutter mask targets, which although slightly stronger than surrounding clutter, are not visually obvious. While the dynamic range of the scan converter display is not unlimited, it can tolerate clutter surrounding slightly stronger targets to a greater degree and still highlight the small signal difference that indicates a target in a region of

clutter. Since less processing is required, more of the radar video can be used and there is less chance of processing a target out of the display.

v) The raster scan output of the system permits the display to be sent to multiple remote black and white monitors. TV montiors do not require a light hood like the PPI and can be viewed from a distance.

vi) The scan converter display can be recorded directly onto video tape for future analysis. Video tape records have proven useful for interpreting ice movements over long periods of time (i.e. greater than 12 hours). Of course this is analogous to time-lapse photographic processing, also possible.

3.7 Small Signal Response to the Scan Converter

The results of the Cape Norman and Tarsiut experiments placed importance on comparatively small differences within the radar video signal. It is necessary to know how the scan converter responded to small signal changes in the video input.

3.7.1 Scan Converter Response Measurements Prior to Field Work

In order to store the radar video signal in real time a compromise between fast writing speeds and display quality was necessary. The specifications of the scan converter list the maximum writing speed as 450 Us/line. To store the radar video on a 6 nautical mile range it is necessary to write the information over a period of 75 U sec. In PPI format this means writing a radial line over half the width of the scan converter

storage target in 75 U sec, or an average writing speed of 150 U sec/line.

The Decca 914A set at six nautical miles short pulse runs with a pulse repetition frequency of 1700 Hz. Since the antenna revolves at approximately 2 seconds per revolution this results in 3400 radial lines being written on the scan converter over 360 degrees.

When the system was first used the radial line structure could be discerned visually just at the outer edges of the display when the azimuth was represented by 10 digital bits.

With the radar on 6 nautical miles short pulse, the minimum write overlap would occur at the outer edges, in the order of 3.3 (= $3400/2^{10}$); i.e. 3.3 successive writes would occur on one written radial line on the scan converter before the least significant bit in the digitized azimuth changed, causing the writing to shift to an adjacent line. Of course approaching the centre of the display the overlap increases, since the written lines have a constant finite width (spillover). It was expected that maintaining this minimum write overlap would offset the fast write speed. It was a third of the maximum write speed specified. Before the field work began the scan converter had been tested with a sine wave input set up to reflect expected conditions and voltages, including writing speed and projected overlap during writing, based on a 10 bit digitized azimuth.

The results indicated that the overlap in writing adequately compensated for the faster writing speed, up to a video frequency of almost one megahertz. They also indicated the settings that

would be required on the scan converter to get the proper electrical response. These settings were then adjusted in the field for best visual effect, but remained in the area of the original settings.

The short interval between system construction and the field work did not permit any further electrical testing of the effects of the high writing speed. (The digitization of the azimuth was later increased to 12 bits (see Section 4.1) to smooth out the display. This, however, does not appreciably change the outer edge overlap ratio calculated).

3.7.2 Post Field Work Measurements

Subsequent to data collection the question arose as to just how much dynamic range was available at the writing speeds involved. A staircase voltage generator was constructed for this purpose to replace the sine wave previously used. To reproduce a staircase waveform, the control settings on the scan converter had to be significantly different from those settings used during data collection.

Figures 3, 4 and 5 illustrate the response of the scan converter to a staircase waveform for the field settings. From the response to 3 writes (Figure 4) and 12 writes (Figure 5) we can assume that during actual operating conditions the minimum overlap lay somewhere well above 3 and could have approached 12, since the radar images were quite easily visible. However, the transfer function in the process of recording and reading back the video leaves a lot to be desired. Compression of the video

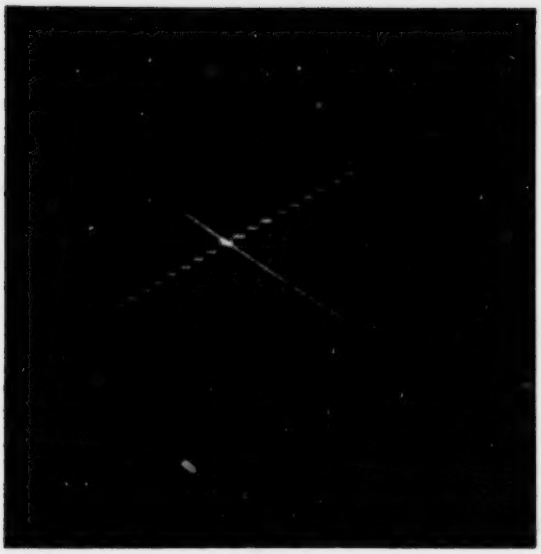


Figure 3

Video input to scan converter: 22 step staircase, 100 mV to 800 mV in 75 μ sec. X-deflection input: linear falling ramp, 2.5 V (full deflection) to 0 V (no deflection) in 75 μ sec. Y-deflection input grounded. This caused the staircase to be written in the direction of a T V line (i.e. horizontally).

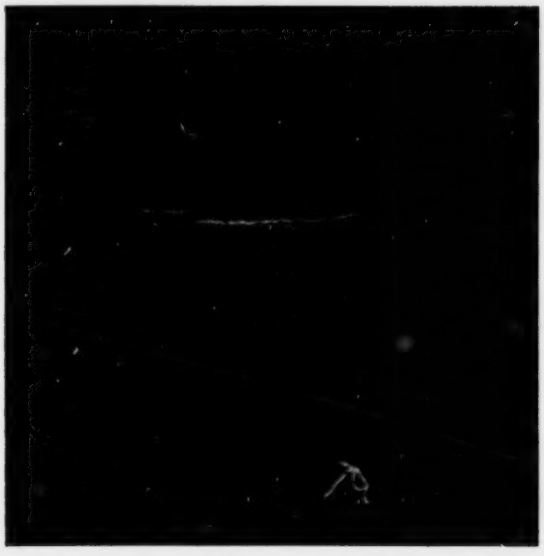


Figure 4

Video output from scan converter after line overwritten 3 times with settings used on first three field trips. Output represents single T V line. 5 μ sec/div. 200 mV/div.

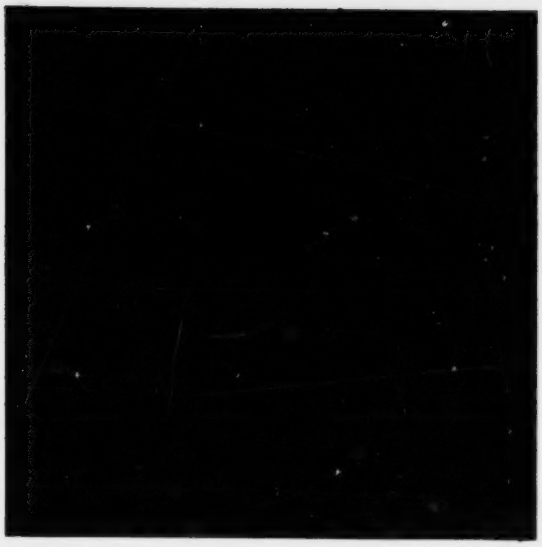


Figure 5

Video output from scan converter after line overwritten 12 times with scan converter settings as used in first three field trips. Output represents single T V line. 5 μsec/div. 200 mV/div.

occurs at both ends of the staircase. While compression can be tolerated for the high end of the video it is crucial to preserve the low end accurately.

Figures 6, 7 and 8 demonstrate the sensitivity of the scan converter when the appropriate settings were found. Note the necessity of reducing the video signal to approximately 2/3 of its previous value, in order to obtain a linear response.

Another consideration is the change with time of the characteristics of the storage tube in the scan converter. It was found that the sensitivity (using a sine wave input identical to the calibration performed before the field work) of the scan converter had decreased significantly (almost 6 dB) over a period of approximately one year. Hence the post field work calibration is not an exact indication of what the response of the scan converter was under field conditions 6 months earlier.

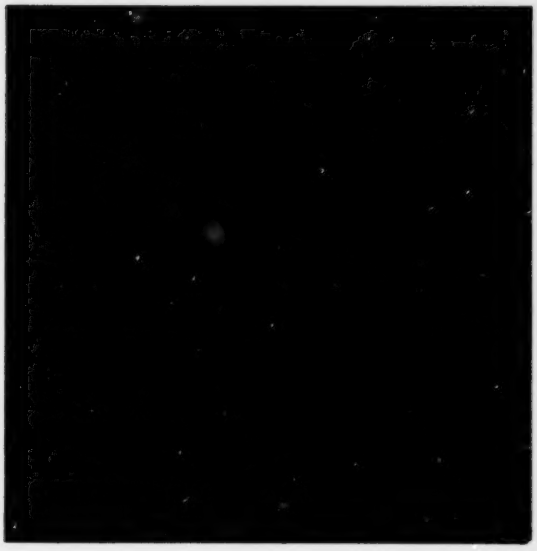


Figure 6

Video input to scan converter: 16 step staircase - 120 mV to 500 mV in 75 μ sec. X-deflection input: linear falling ramp 2.5 V (full deflection) to 0V (no deflection) in 75 μ sec. Y-deflection input grounded. This caused the staircase to be written in the direction of a T V line.

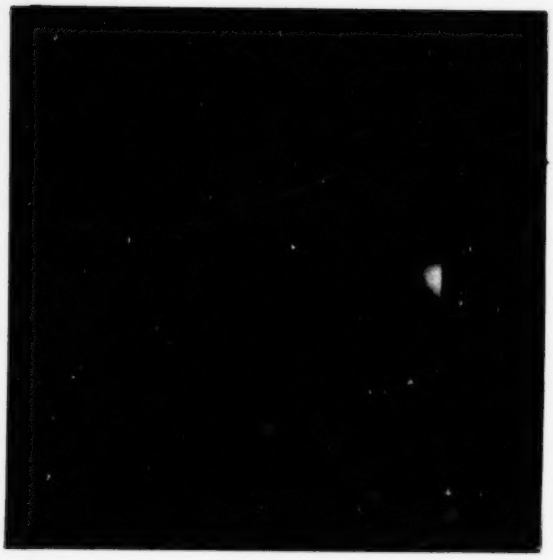


Figure 7

Video output from scan converter after line overwritten 3 times with scan converter settings adjusted to optimize electrical output. Output represents single T V line. 5 μ sec/div. 200 mV/div.

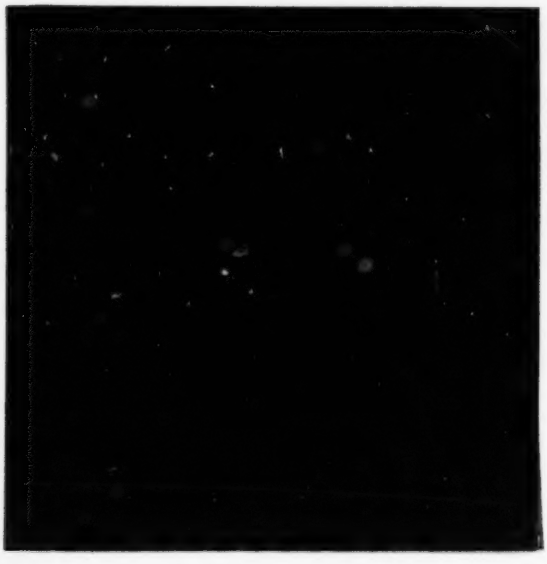


Figure 8

Video output from scan converter after line overwritten 12 times with scan converter settings adjusted to optimize electrical output. Output represents single T V line. 5 μ sec/div. 200 mV/div.

Figure 9

Cape Spear December '81. The Canadian Coast Guard's Vessel Traffic System (centre) overlooks Cape Spear. The roof of the building to the right shielded targets from the radar. (Section 4.1).

Figure 10

4. FIELD WORK

Between December 1981 and the end of May 1982, three field trips were made with the display system interfaced to a marine radar.

In all cases the interface was made to Decca X-band radars. The only significant difference between systems occurred on the last field trip, where transmit power was approximately four times that used previously.

4.1 Cape Spear, Newfoundland, December 1981

The operational testing of the system started in mid-December at Cape Spear, Newfoundland. The Canadian Coast Guard in Newfoundland had moved their Vessel Traffic Systems unit (see Figure 9) to Cape Spear (elevation 65 m). C-CORE was allowed to interface to the Decca 914A (6 kw, X-band)within the trailer. The radar video was tapped at the appropriate point in the radar before video processing occurred with either STC or FTC.

Technical changes were made during this period to improve the quality of the display. These changes removed a 1 MHz noise component on the scan ramp, improved the detection reliability of the heading marker, and added two synthetic "bits" to the vector generator input. This increased the digitized azimuth to 12 bits and removed the radial structure on the display observed with a 10 bit digital azimuth.

The vector generator produced glitches every 22.5 degrees (see Section 3.6) on radar ranges below 6 n. miles, (attributed to excessive slew rates). Discussions with the manufacturer did

not yield a solution, and this problem remained unsolved.

By December 19, the display system was operational and was recording the flow of vessels to and from the narrows of St. John's harbour as they passed in front of the Cape (Figure 10, page 30).

Sea clutter was always present. During the operational testing the bias and recording levels of the scan converter were adjusted over their full range while the radar video was recorded (Figure 11). This data set was played back on a VP-8 Image Analyzer to determine the effect of the scan converter recording levels on the data.

The conditions of sea clutter were only present at this field location, so it was fortunate that there was one opportunity to record this condition. Figures 12a and b illustrate a typical display recorded during operational testing.

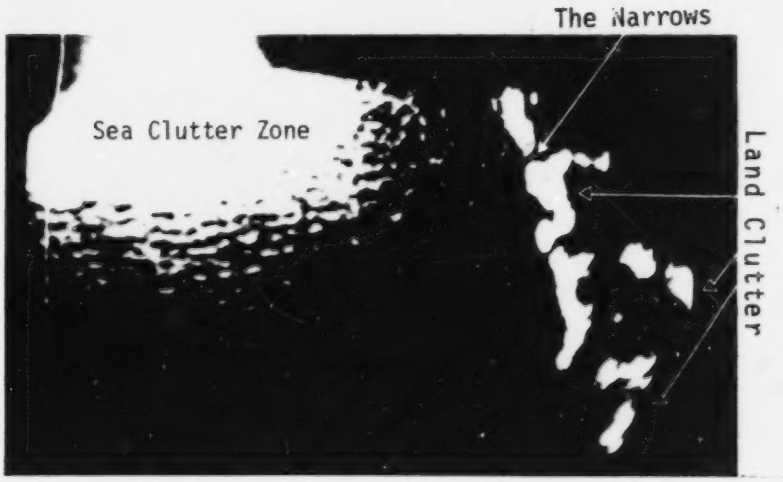
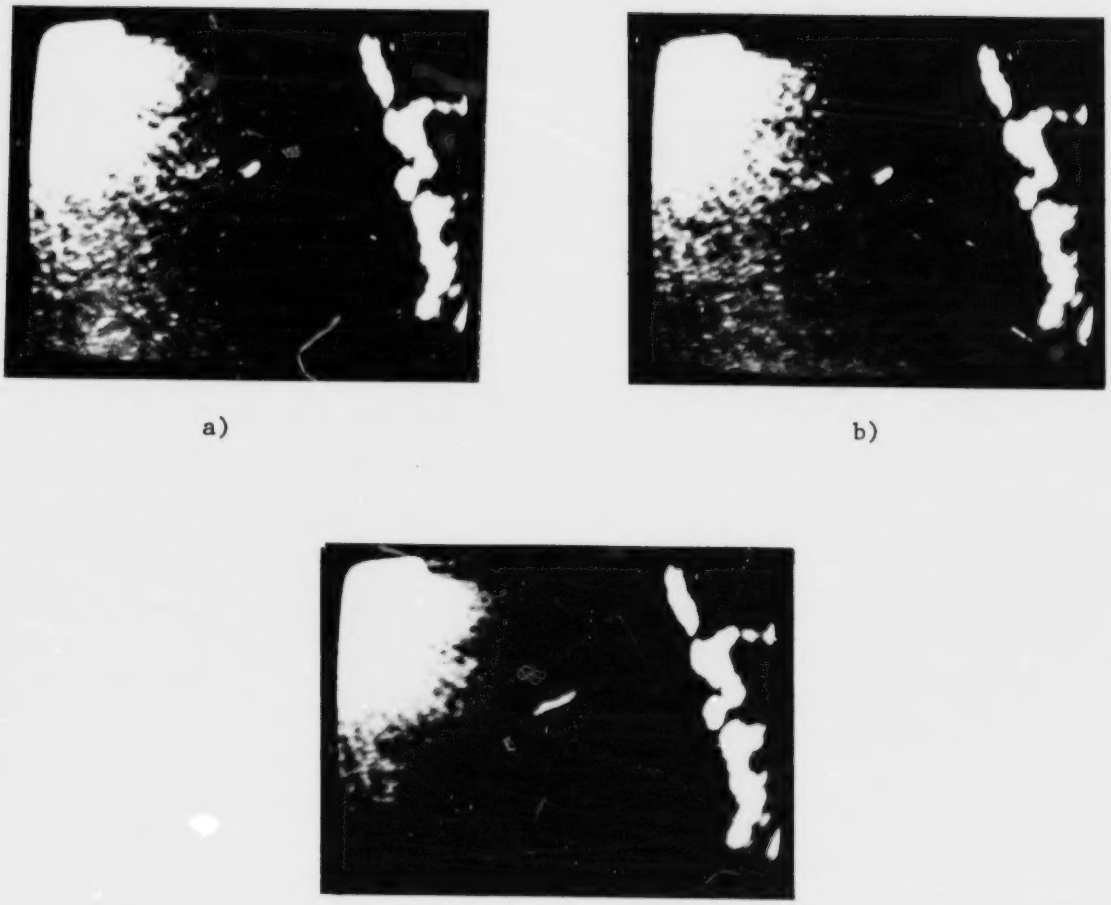


Figure 11

Expanded and off-centre Scan Converter display. The centre of the radar display is in the upper left corner.



a) b)

c)

Figure 12

Effect of photographic averaging on sea cutter

Display a and b were photographed approximately 50 seconds apart. A ship was passing through the clutter zone of the radar on its way to St. John's. At the time of recording, the zoom control was used to expand the lower right quadrant to fill the screen. The centre of the radar display is in the upper left corner. The ship is near the centre of the screen at the edge of the clutter zone. Land clutter fills the right side of the display. The harbour entrance is the top most gap between the land returns. Random dashes indicate radar interference from a second radar. Note the strength of the sea clutter and the area affected. In photo c, a camera was used to photographically average eight displays representing a time interval of approximately 58 seconds. Compare the sea clutter zone here with photos a and b.

4.2 Cape Norman

In early April (1982) the Coast Guard's VTS unit had been moved to Cape Norman (about 17 m elevation) overlooking the Strait of Belle Isle (see Figures 13, 14 and 15). As in Cape Spear, C-CORE was given the opportunity to interface to the Decca X-band radar (see Figure 16). From April 22 to the 25, 220 minutes of scan converter display was recorded.

During that time, first year sea ice drifted up the Strait (see Figure 14). The ice coverage remained consistent at 10/10 (AES terminology). Occasionally a section of open water surrounded by ice floes passed through our field of view. All the floes had an upper layer of snow and the edges had been built up, probably from the grinding action of one floe against the next. Typical floes can be seen in Figure 17 which shows the ice that had drifted into the bay between Cape Norman and Whale Point.

Both long (0.75 Us) and medium (0.25 Us) pulse lengths were used on the Decca 914A. Although the long pulse increased range of detection it was at the expense of spatial resolution.

Apart from real time recordings of the display system, two time lapse video recordings were made, by repeatedly pausing the recording tape deck manually after recording a short length of the video.

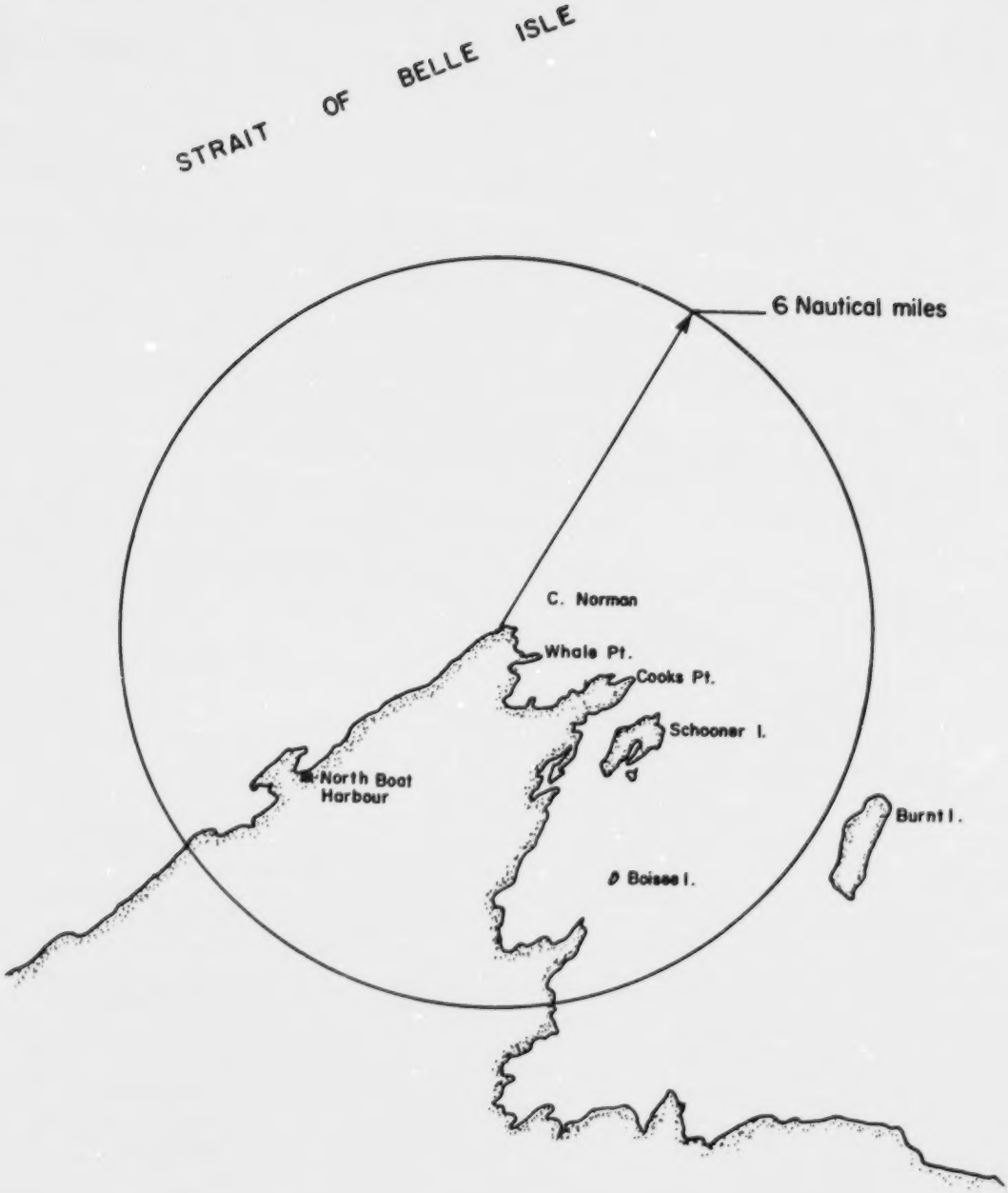


Figure 13. Cape Norman, Newfoundland

Figure 14.

April '82. Coast Guard's VTM unit at Cape Norman at the edge of the Strait of Belle Isle. First Year sea ice covers the Strait.

Figure 15.

April '82. Cape Norman. A view of the coast along the Strait. The radar antenna is just visible above the rocky edge (centre of photo).

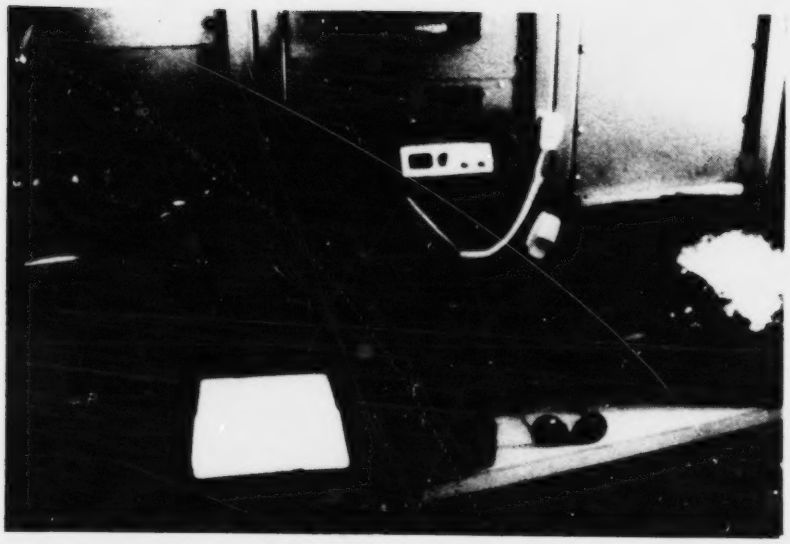


Figure 16

April/82. Inside the VTM unit. The Decca 914A x-band radar is on the left side. The scan converter display is brought up on the black and white monitor (right side).

Figure 17

First year sea ice in the small bay between Cape Norman and Whale Point. Strait of Belle Isle in background.

4.3 Tarsiut Island (Long. 136° 12′W, Lat. 69° 53′)

The last field trip occurred on Tarsiut Island in the Beaufort Sea about 70 miles from Tuktoyaktuk (see Figure 18 and 19). This was a joint effort between Gulf Canada Resources Ltd. and C-CORE. Gulf was interested in the system from the point of view of monitoring and recording ice movements around the artificial island. For C-CORE this was an opportunity to look at fast ice, ridges, and open leads.

The system was installed on a Decca 914A with a 25 kw output (previous installations had been on 6 kw Decca systems). Recording of data started May 18, 1982 when the ice around Tarsiut was fast (out to 8 nautical miles and beyond). The radar antenna elevation was 20 m. The last recording made was June 2, 1982.

C-CORE's representative left on May 21 but the ice observers on the Island kept the system running until June 2, 1982. By that time the northern half of the ice sheet around Tarsiut had broken up.

Two types of 3/4" video tape decks were used, a standard portable cassette for display in real time and a time lapse deck capable of placing 96 hours of display onto a 60-minute cassette tape.

Two significant problems affected the quality of the recordings.

Having a second radar on the island (a Furuno) caused constant radar interference on most of the recordings taken prior to May 20. After that time the Furuno became inoperable for

reasons unknown to C-CORE. The main problem, however, was the poor quality of the recordings made on the video time lapse decks. Either the time lapse machines could not endure the frequent brown-outs on the island, or they had been damaged during transport to Tarsiut. Two decks (both cassette type) were tried, but both produced distorted images on playback. The time lapse decks were returned before the problem could be diagnosed.

Unfortunately, the time lapse decks had been used from the beginning of the ice break up, so a large percentage of the cassette recordings could not be processed.

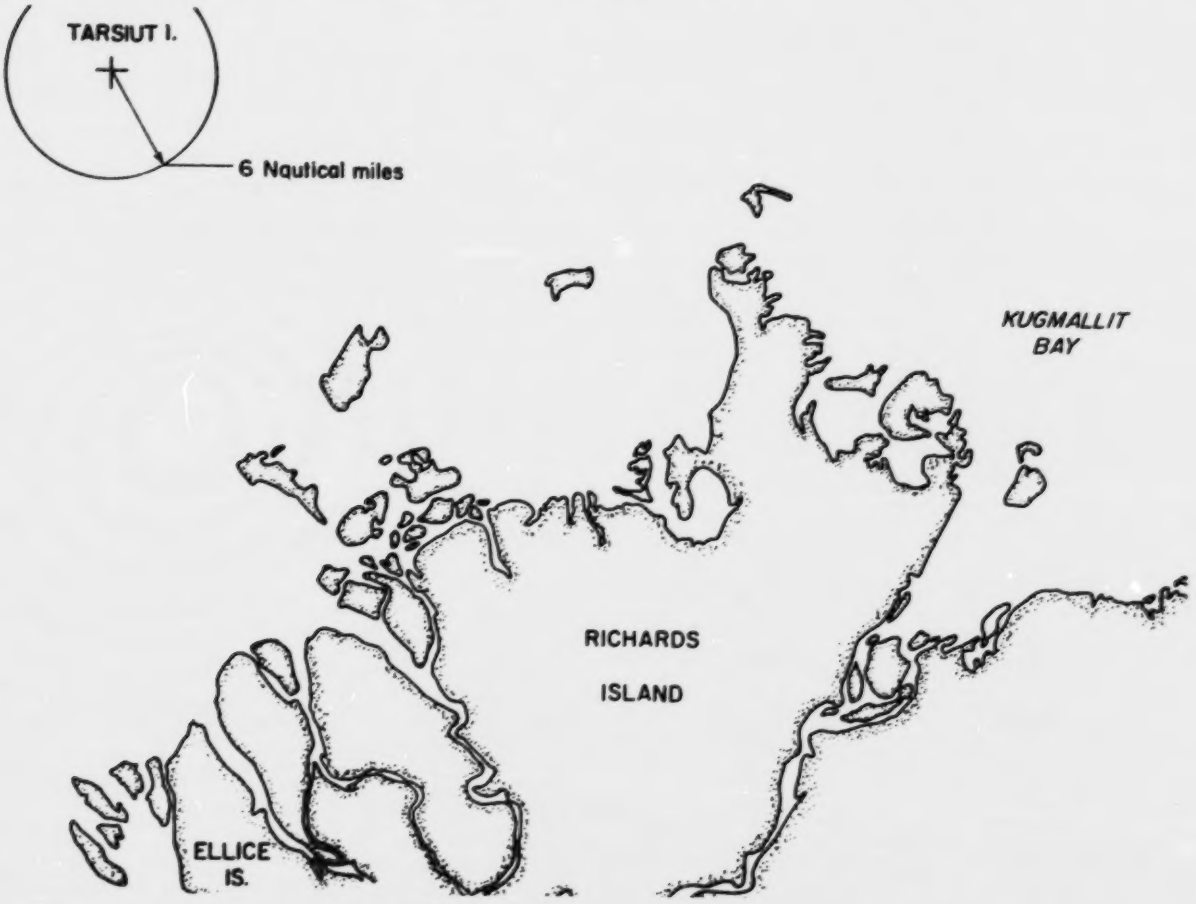


Figure 18. Tarsiut Island, Beaufort Sea, N.W.T.

Figure 19

Aerial view of Tarsiut Island, Beaufort Sea. Ice ridges (first year) zig zag around the island.

5. PROCESSING DISPLAY IMAGES

5.1 Scan Integration

Scan integration causes the information from successive sweeps to be added and then normalized. All the radar video can be used if the display has sufficient dynamic range (i.e. if premature saturation of the display can be avoided).

This averaging process will minimize statistical signals like sea clutter which fluctuate with time leaving non-statistical targets essentially unaffected.

Photographs a and b of Figure 12 were generated from a video tape playback of the scan converter display recorded at Cape Spear, Newfoundland (Section 4.1, see page 33). Note the outer zone of sea clutter and the distinct returns from various points within that region. Now compare these with photograph c, which is a multiple exposure of 8 successive displays. The camera's aperture was reduced to counteract the extra light from multiple exposure. This is not Scan Integration in the strict sense, because light intensities can only be added on film. It demonstrates, however, the effect of integration on sea clutter.

The ship was a consistent target giving a strong image whose track indicates its position had changed. On the other hand, the outer region of sea clutter had smeared to a more uniform background because of its statistical nature from scan to scan.

Scan integration did not improve the interior range (upper left hand corner). The video was probably saturated. Some gain control would have been appropriate here.

5.2 Post Processing Techniques

Three forms of processing were applied to the display data recorded: image slicing using a VP-8 Image Analyzer at Memorial University; pseudo-Scan Integration using photography; and image analysis using the Norpak system at Remotec Applications Inc.

5.2.1 Image Slicing

The VP-8 Image Analyzer is used to slice an image (based on intensity levels) into eight bands from black to white. The levels for each band can be altered to suit the situation. The resultant image is quantized into eight grey tones including black and white. The data from Cape Spear was processed to determine the region of the scan converter's video occupied by noise and targets.

The VP-8 with only 8 levels, although useful, cannot analyse the data to a more useful number like 16 or 32, and so approach the dynamic range of the scan converter. Also, it does not produce a permanent record of its ice analysis. The system's monitor had to be photographed to keep a record of each analysis.

5.2.5 Photographic Integration

From data collected at Cape Norman, Newfoundland (Section 4.2) it became apparent that the ice floes produced vaerying radar returns from scan to scan as they drifted through the radar's field of view.

A 35 mm camera, with Kodak Panatomic-X film, was used to average several successive displays by adjusting the aperture and

exposure time. This method, however, only approximates integration; the film can only add intensities, not subtract as in true integration.

5.2.3 The Norpak System

This sytem can digitize a single raster frame, using a range of 256 intensities. Once a series of frames have been digitized the data can be manipulated in any fashion required using the accompanying Hewlett Packard 1000 computer. All data can be stored subsequently on magnetic tape.

This system was used to analyze selected sections of the recorded video data from the last two field trips.

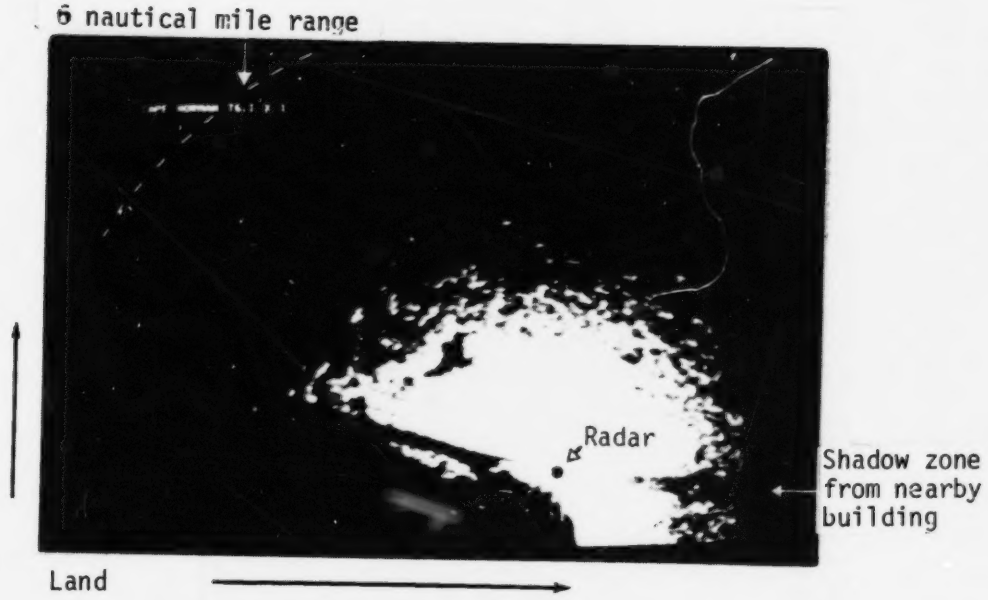


Figure 20

Norpak system display of video tape data collected with scan converter. Video tape image is of sea ice returns from Cape Norman, using Decca 914A on 6 nautical miles range, long pulse. Scan converter was adjusted for off centre display with partial zoom. First year sea ice coverage was "10/10" with a few visible patches of open water.

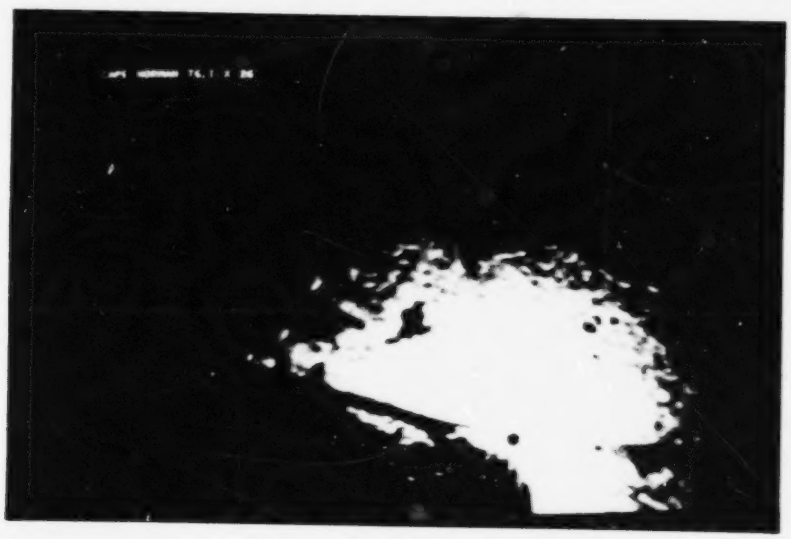


Figure 21

The result of digitizing, integrating, and then normalizing 26 radar images from scan converter display. The 26 images represent an interval of 2.6 minutes of radar time and approximately one third of the available radar sweeps during that interval. The first image in the series of 26 is shown in Figure 20.

6.0 DISCUSSION OF RESULTS AND OBSERVATIONS

This section will look at the system noise in the video and the returns from First Year Sea Ice (FYSI) qualitatively, and illustrate improvements to the display.

6.1 Discussion

The noise region of the video provides the background of the display. Figure 20 was obtained by stretching and digitizing a single scan converter frame of FYSI on the Norpak system described in Section 5.2.3. The background of the display, beyond the FYSI returns, appears as speckle which is not a particularly desirable feature. Integration will smooth the background as illustrated in Figure 21, in which twenty six frames, the first of which appears in Figure 20, have been stretched, digitized, and integrated.

To illustrate the adverse role of speckle on range of detection, the image intensity as function of distance to the centre of the radar image for fixed azimuth was graphed for two different azimuths from both figures. The intensity distributions are illustrated in Figure 22. Figure 22 a,b give intensity as a function of range at two different bearings for Figure 21 (integrated image). Figure 22 a,b indicate that the range of detection was roughly 4.5 to 4.75 nautical miles, along the indicated bearings. This is based on the ratio of I_o (object intensity) to I_s (sorrounding intensity), approximately 1.3, exceeding a minimum contrast ratio of 1.03 (see Sherr, 1970).

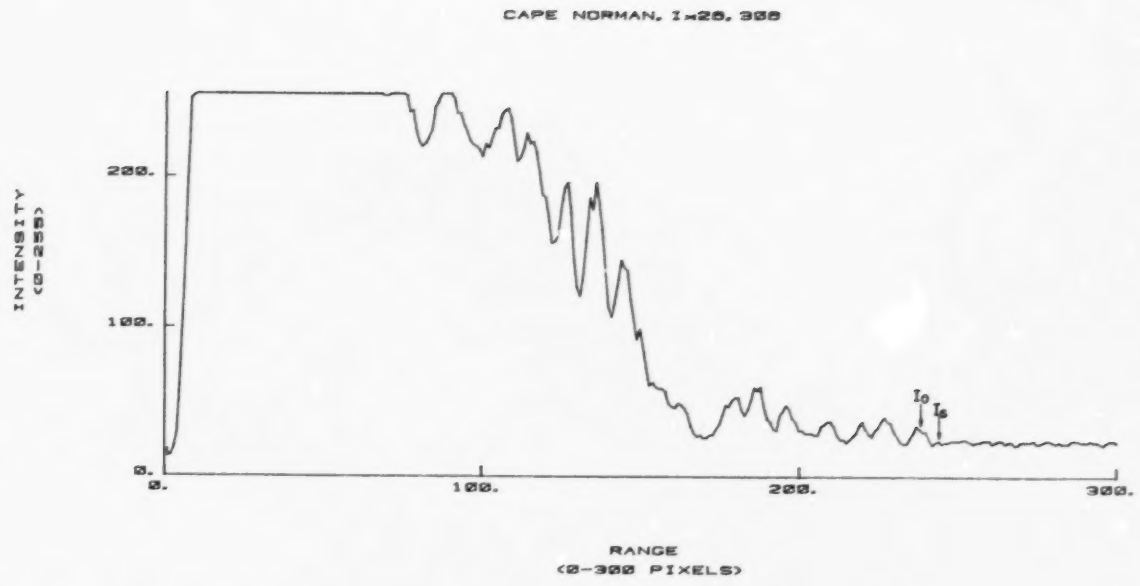


Figure 22a

Intensity distribution 0 to 6 nautical miles, bearing 306°. 300 pixels corresponds to approximately 6 nautical miles.

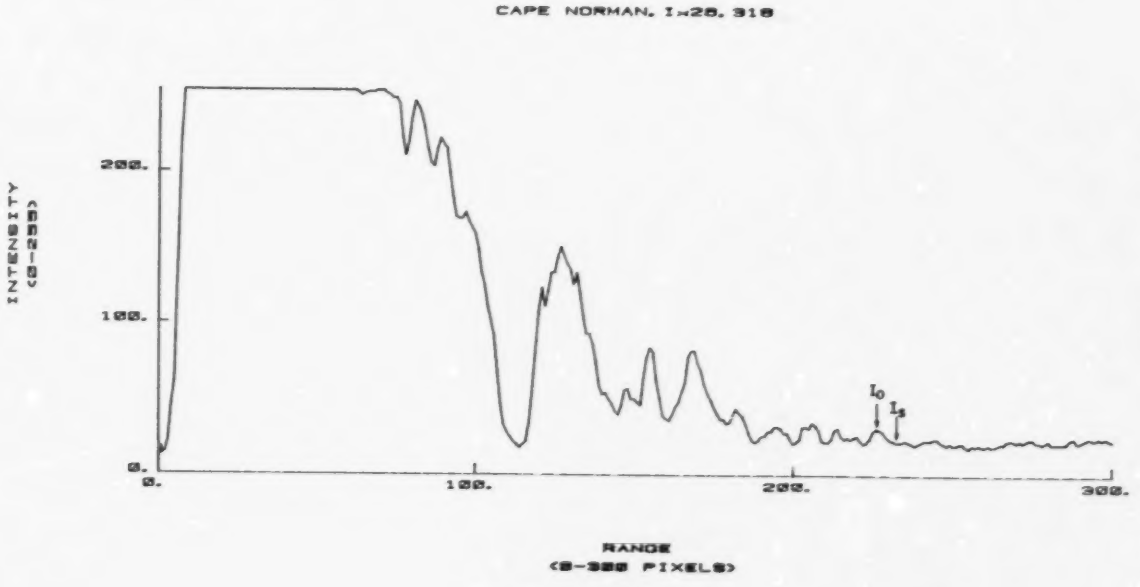


Figure 22b

Intensity distribution 0 to 6 nautical miles, bearing 318°.

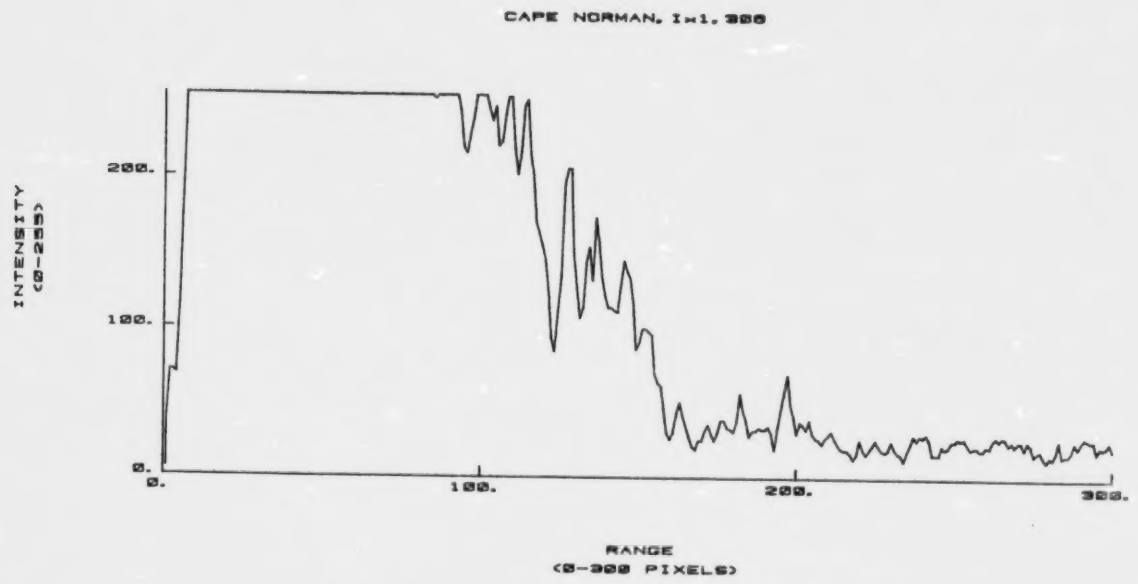


Figure 22c

Intensity distribution 0 to 6 nautical miles, bearing 306°. 300 pixels corresponds to approximately 6 nautical miles.

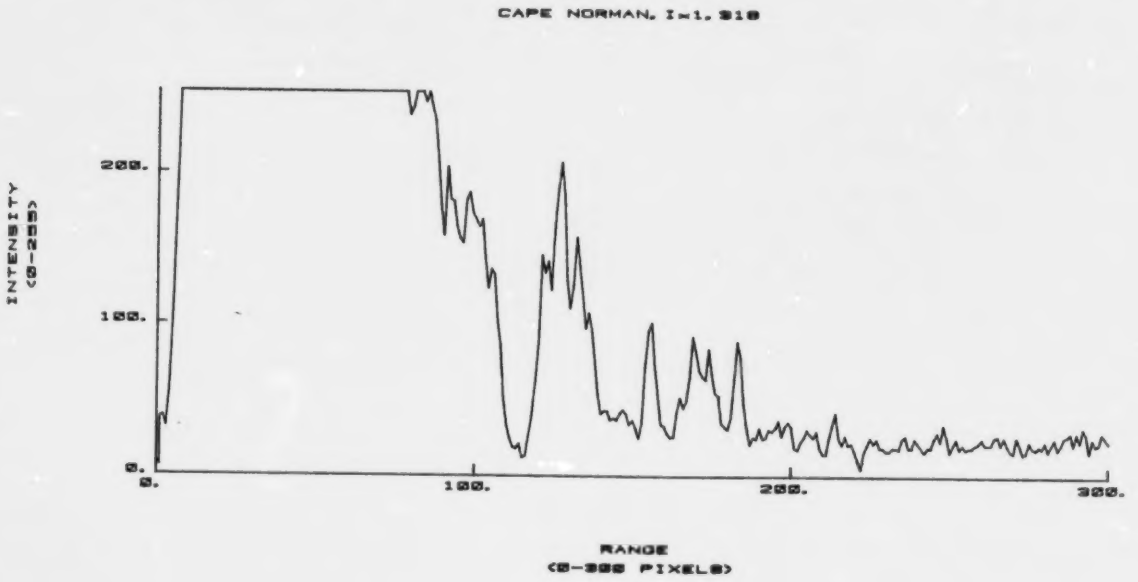


Figure 22d

Intensity distribution 0 to 6 nautical miles, bearing 318°.

By comparison Figure 22 c,d illustrate the adverse role of speckle in the background. What is the range of detection for the case of a single scan? Likewise beyond 4 nautical miles, how many targets are there along each bearing?

Comparison of the two displays in Figure 23 shows the typical variation in target returns from one scan to another. Although the time interval represented is 19 seconds, monitoring of the PPI indicated the same variation from scan to scan (2 to 3 seconds). The inconsistenccies in ice returns from scan to scan hinder the interpretation of the display. It is analogous to viewing a jigsaw puzzle a number of times with a different random selection of pieces missing each time. A good memory is required to obtain the full picture. Integration of a series of these displays should help the interpretation process under these conditions. The inconsistencies in the returns, which tend to mask any shade patterns, would be minimized.

A time series of photographically averaged data representing approximately 4.7 minutes of radar time is shown in Figure 24. Note the nearly vertical feature in the upper third of the first photo. This feature can be seen in every photo of the time lapse sequence but the original data set of single frames gave no indication of its existence. The feature was first identified when the photographically averaged data was being reviewed.

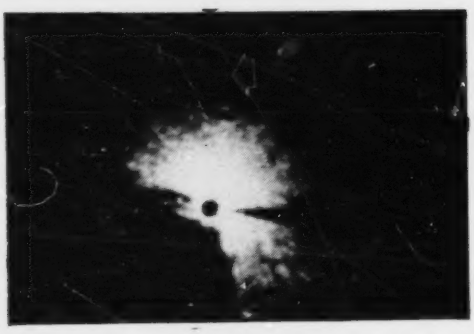
At Tarsiut Island, almost all radar returns could be attributed to the presence of ridges.

Both the scan converter display and the radar PPI showed the same basic target information. The main difference was the

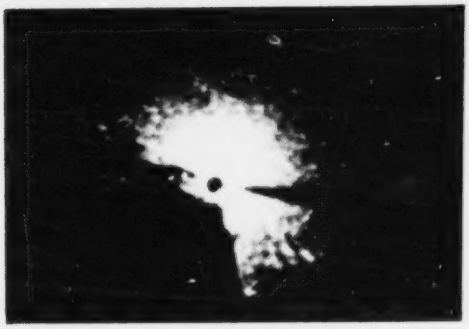
spread of intensity over which the targets were displayed with the scan converter indicating weaker strength targets (compared to the PPI) at the farther ranges.

Figure 25 illustrates a typical scan converter display taken at Tarsiut. For purposes of comparison, Figure 26 shows the corresponding PPI display. Radar returns five nautical miles to the southeast showed a large 8 metre ridge which ran perpendicular to the radar look direction. Figures 27 to 31 indicate the results of integrating sequences of this display. The speckle background smoothes out after integrating 5 images, Figure 27, and the weak target contrast improves as well. In particular, a weak pattern suggests a continuation of the ridge to a point almost due south of the island.

Figure 32 shows the results of applying spatial filtering to Figure 31. The object was to enhance further the weak pattern in question. For comparison, Figure 33 shows the result of applying the same spatial filter technique as used for Figure 32 to the single display in Figure 25. Since the noise region represents a considerable percentage of the total video signal, spatial filtering without integration will not improve the image.



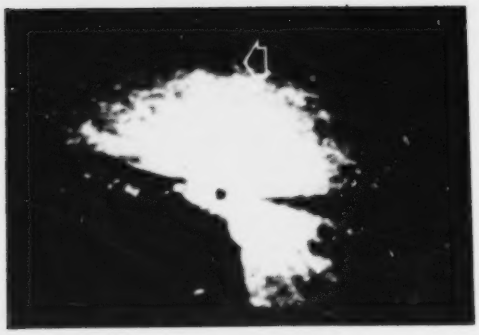
a)



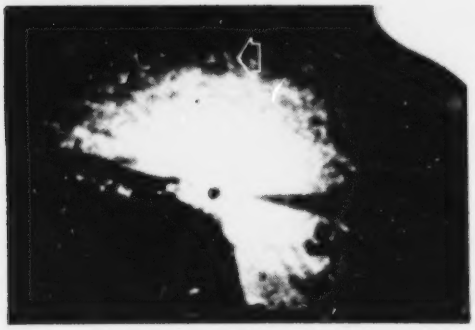
b)

Figure 23

Two scan converter radar images of first year sea ice (floe) returns taken approximately 19 seconds apart, from the Strait of Belle Isle. From the radar centre to the top of the screen is approximately 2.3 nautical miles. Fig.a) shows an almost vertical feature almost directly above the centre of the radar. Fig. b) indicates the random nature of sea ice returns from scan to scan. The vertical feature is not visible.

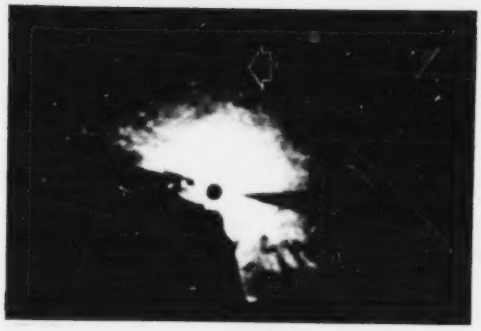


a) t = 0 sec.



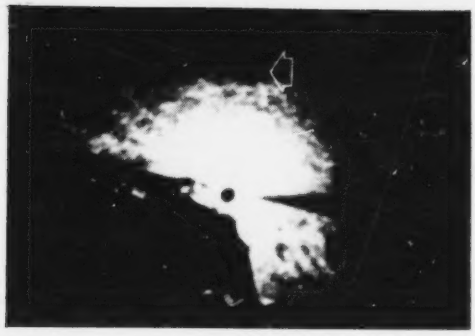
b) t = 48 sec.

Figure 24

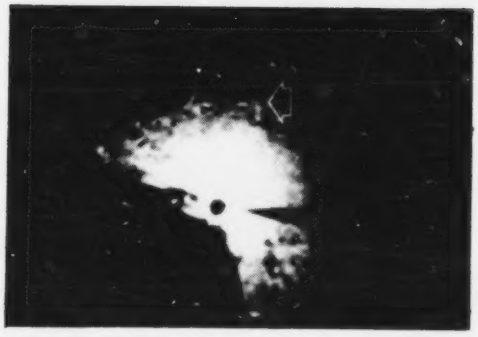


c) t = 101 sec.

d) t = 154 sec.



e) t = 212 sec.



f) t = 246 sec.

Figure 24

Photographic averaging of sea clutter: a-f were made by photographically averaging short stretches of scan converter data set recorded from the Strait of Belle Isle. Each photo typically represents the average of 4 successive displays. Note that the position of the vertical feature is easily followed as it slowly moves to the right.

Figure 25

Scan converter display of first year sea ice returns about Tarsiut Island (centre of the display) photographed from the Norpak system monitor. Decca 914A (modified) was set on 6 nautical miles, short pulse. A large shadow sector exists between 0° and 30°. A smaller shadow sector also occurs at approximately 50°.

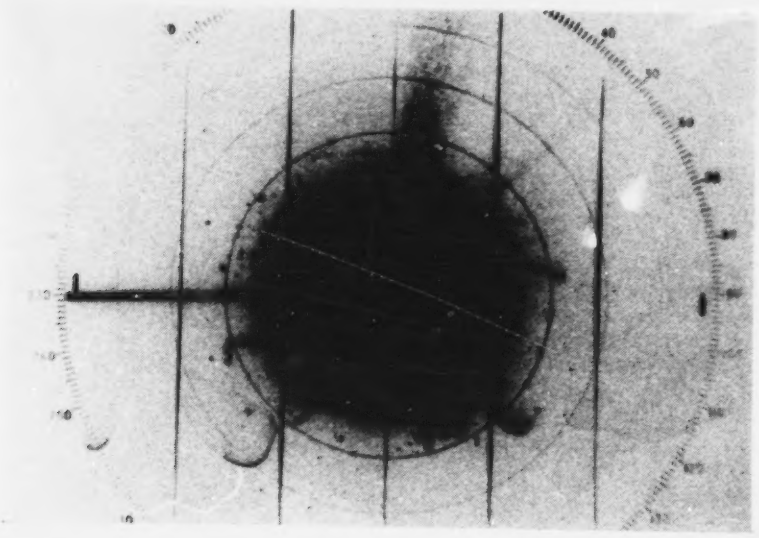


Figure 26

Photo of Decca radar display on Tarsiut Island, Beaufort, May 20/82. The radar was set on a 12 nautical mile range. (Compliments of Gulf Canada Resources).

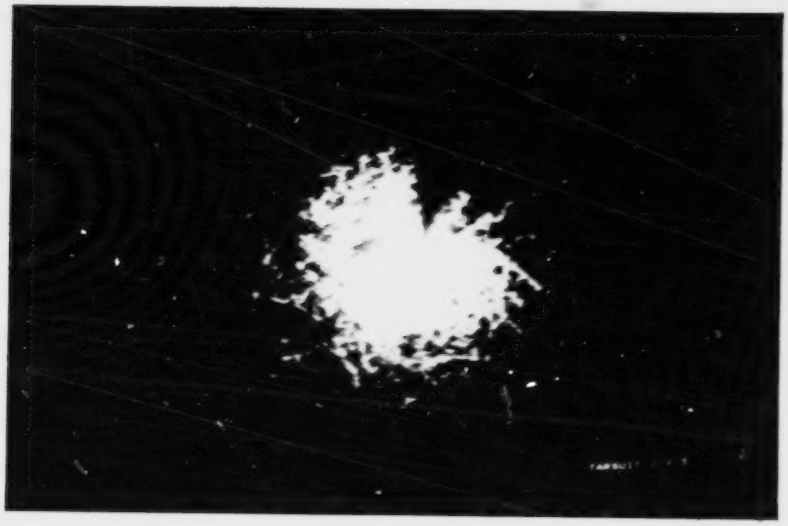


Figure 27

The result of integrating and normalizing 5 images from scan converter display, representing an interval of 2.3 minutes radar time, and approximately 8 percent of the available radar sweeps during that interval. The first image in the series of 5 is shown in Figure 25.

Figure 28

The result of integrating and normalizing 10 images from scan converter display, representing an interval of 4.6 minutes radar time and approximately 8 percent of the available radar sweeps during that interval.

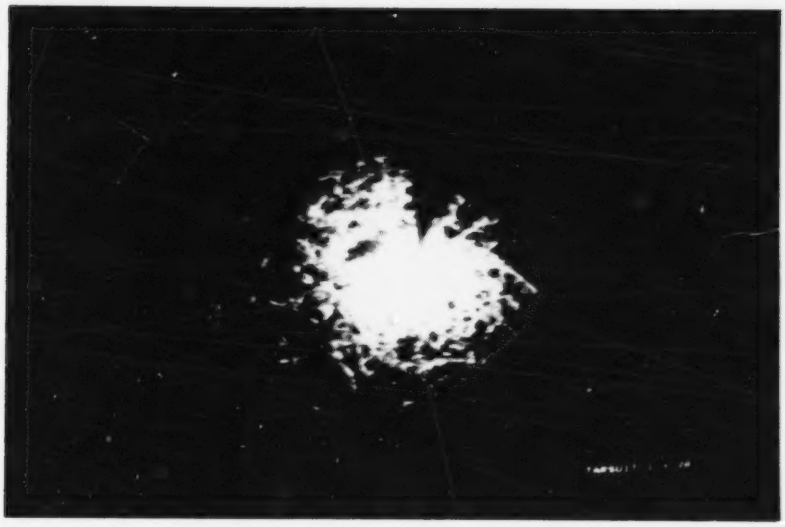


Figure 29

The result of integrating and normalizing 20 images from scan converter display, representing an interval of 9.2 minutes radar time and approximately 8 percent of the available radar sweeps during that interval.

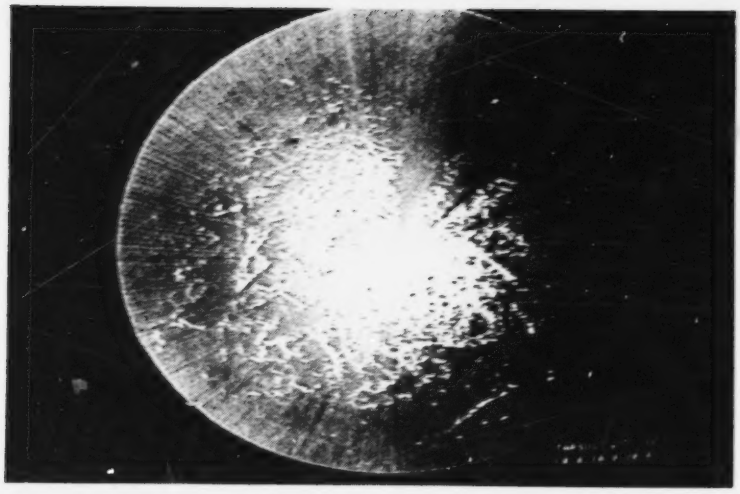
Figure 30

The result of integrating and normalizing 30 images from scan converter display, representing an interval of 13.8 minutes radar time and approximately 8 percent of the available radar sweeps during that interval.

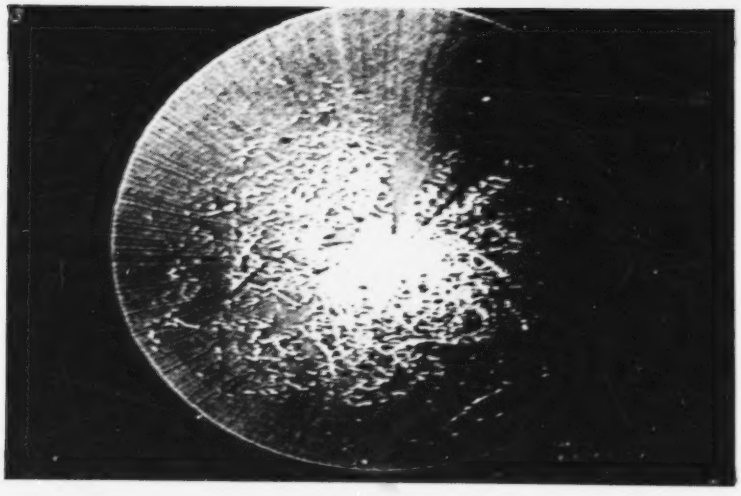
Figure 31

The result of integrating and normalizing 38 images from scan converter display, representing an interval of 17.5 minutes radar time and approximately 8 percent of the available radar sweeps during that interval.

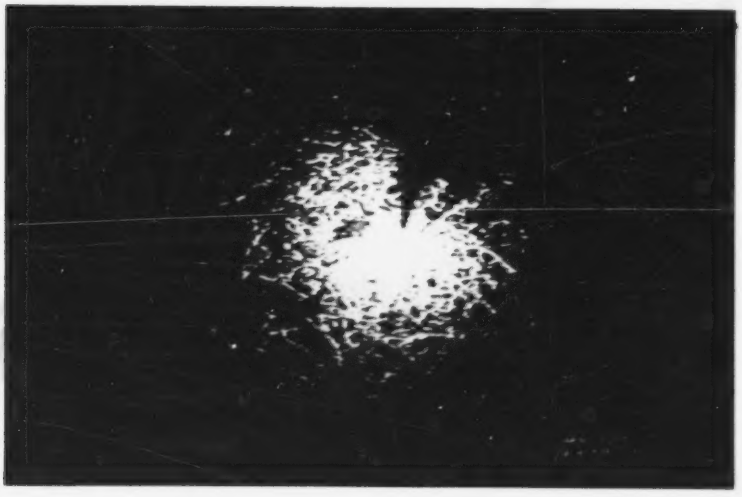
a)



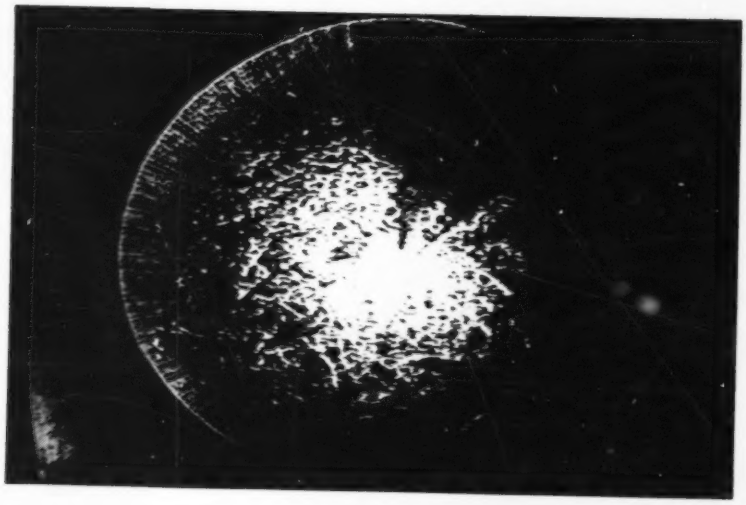
b)



c)



d)



e)

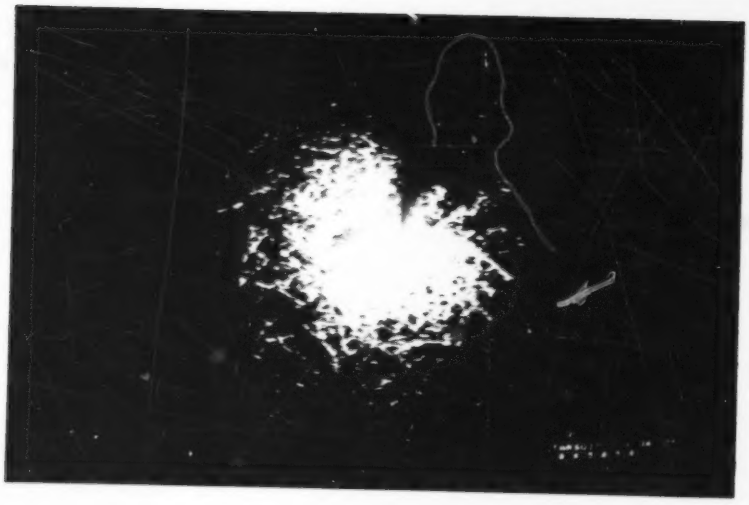


Figure 32

Five different spatial filtering techniques applied to the image shown in Figure 31.

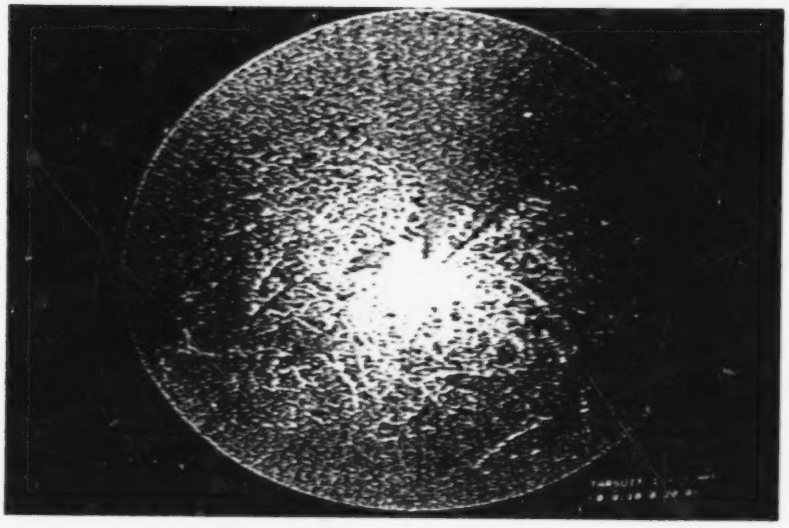


Figure 33

Spatial filtering applied to image in Figure 25.

7. CONCLUSIONS

The statistical nature of marine radar returns from freely floating FYSI and the amount of system noise in the radar video present on interpretational problem that can be mitigated with scan integration and a display with sufficient dynamic range. Spatial filtering can further improve the display, but only if accompanied by scan integration.

The statistical nature of returns from freely floating FYSI on the PPI confuses interpretation by inhibiting pattern recognition.

System noise in the video masks weaker signals that can be significant. The use of a scan converter by itself, without integration, accomplishes little. Its merit is only apparent if scan integration is part of the process. The use of some swept gain (STC) is still required to prevent saturation of the radar video circuit at close range. This was apparent from the centre of the scan converter display images; many were saturated. Scan integration, of course, can accomplish nothing in a region of saturation

Since there were compromises in the scan converter writing speed and recording levels, and the integrated images still were an improvement, it is difficult to say what the limits of improvement are. In particular scan converters that integrate are also commercially available and at least one of them has a faster writing speed than the scan converter used in the data collection.

A similar system could be used with an integrating scan converter, which should out perform the integration results indicated in this report.

REFERENCES

Bell, R.A. (1970) Principles of Cathod-ray Tubes, Phosphors, and High-Speed Oscillography. Hewlett-Packard Application Note 115. Colorado Springs, U.S.A.: Hewlett-Packard Company.

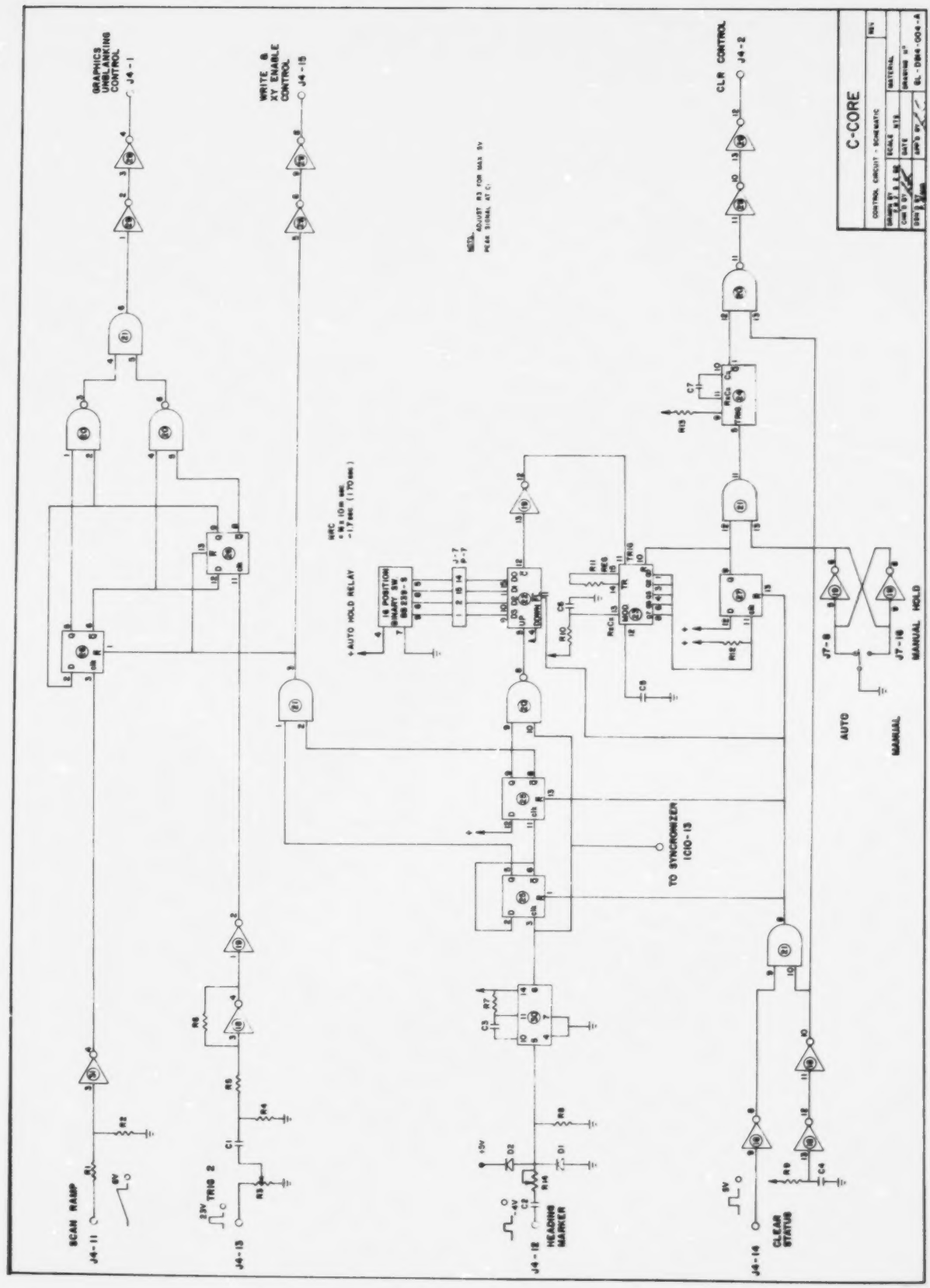
Luxenberg, M.R. and Kuehn, R.L. Eds., (1968) **Display Systems Engineering.** Inter-University Electronics Series Vol. 5. New York: McGraw-Hill Book Company.

Sherr, S. (1970). **Fundamentals of Display System Design.** New York: Wiley-Interscience.

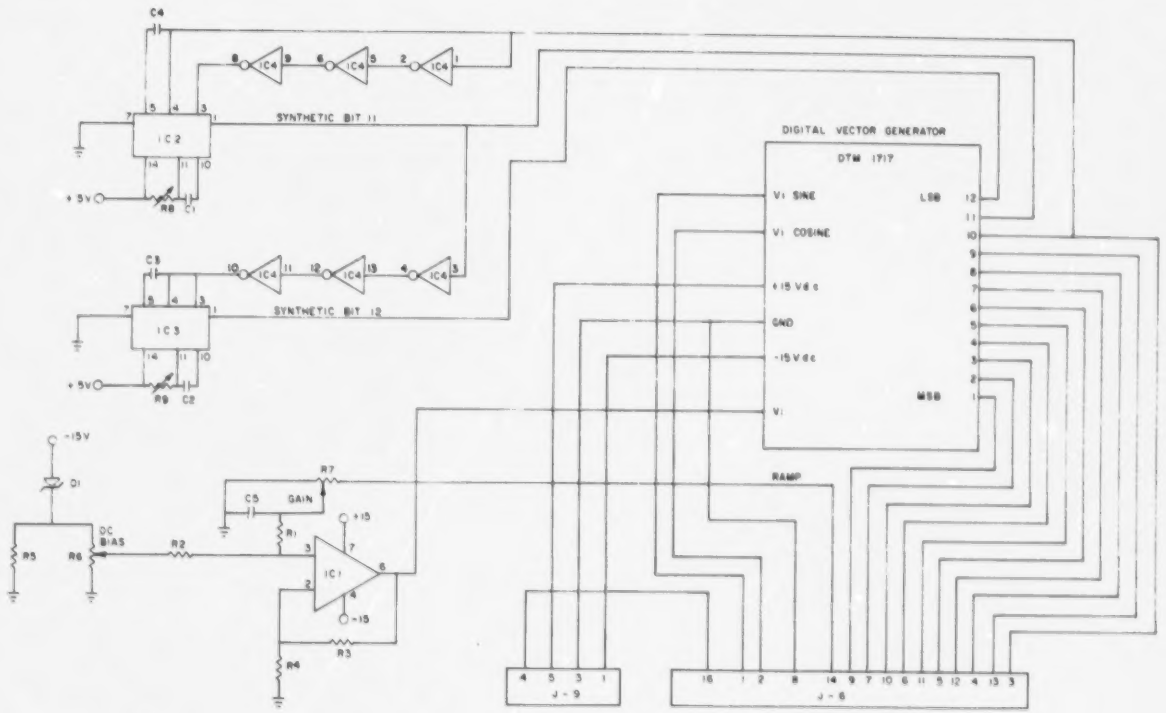
Skolnik, M.I. (1980). **Introduction to Radar Systems** Second Edition. New York: McGraw Hill Book Company.

APPENDIX A

ELECTRONIC DRAWINGS


C-CORE
CONTROL CIRCUIT - SCHEMATIC
GRAPHICS UNBLANKING CONTROL
J4-1
WRITE & XY ENABLE CONTROL
J4-15
CLR CONTROL
J4-2
SCAN RAMP
J4-11
TRIG 2
J4-13
HEADING MARKER
J4-12
CLEAR STATUS
J4-14
+AUTO HOLD RELAY
16 POSITION BINARY SW BB 239-5
TO SYNCHRONIZER IC10-13
AUTO
MANUAL
MANUAL HOLD
NOTE: ADJUST R3 FOR MAX 5V PEAK SIGNAL AT C1

62(A-1)



NOTES

i) ADJUST R6 FOR 0V DC BIAS

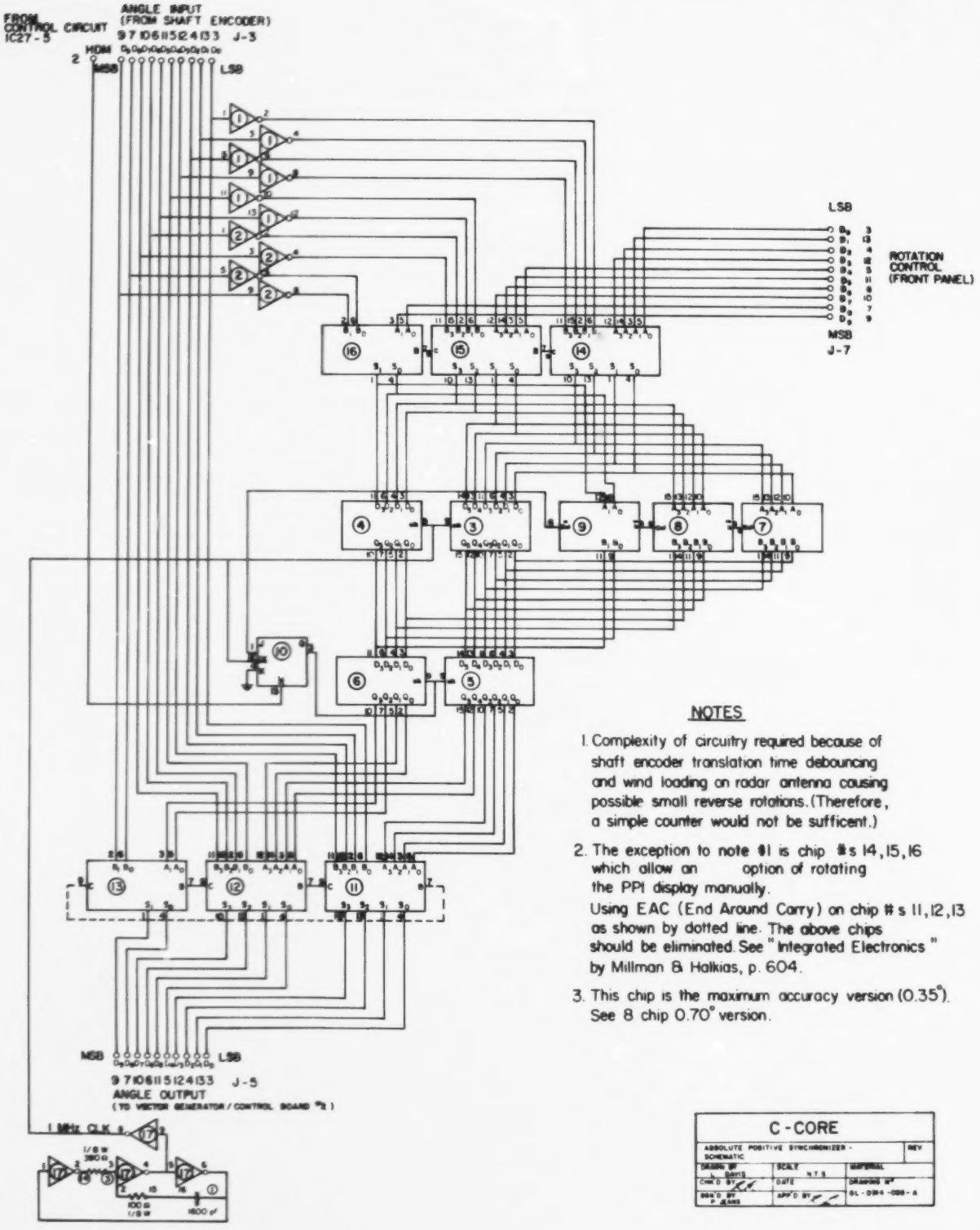
ii) ADJUST R7 TO SET MAX O/P OF C1 AT ± 2.5 V PEAK

iii) ADJUST R8 SO THAT FREQUENCY OF BIT 11 IS TWICE THAT OF BIT 10

iv) ADJUST R9 SO THAT FREQUENCY OF BIT 12 IS TWICE THAT OF BIT 11

v) PICK VALUE OF C5 JUST SUFFICIENT TO REMOVE HIGH FREQUENCY NOISE COMPONENT OF RAMP AFTER i) THROUGH iv) HAVE BEEN PERFORMED

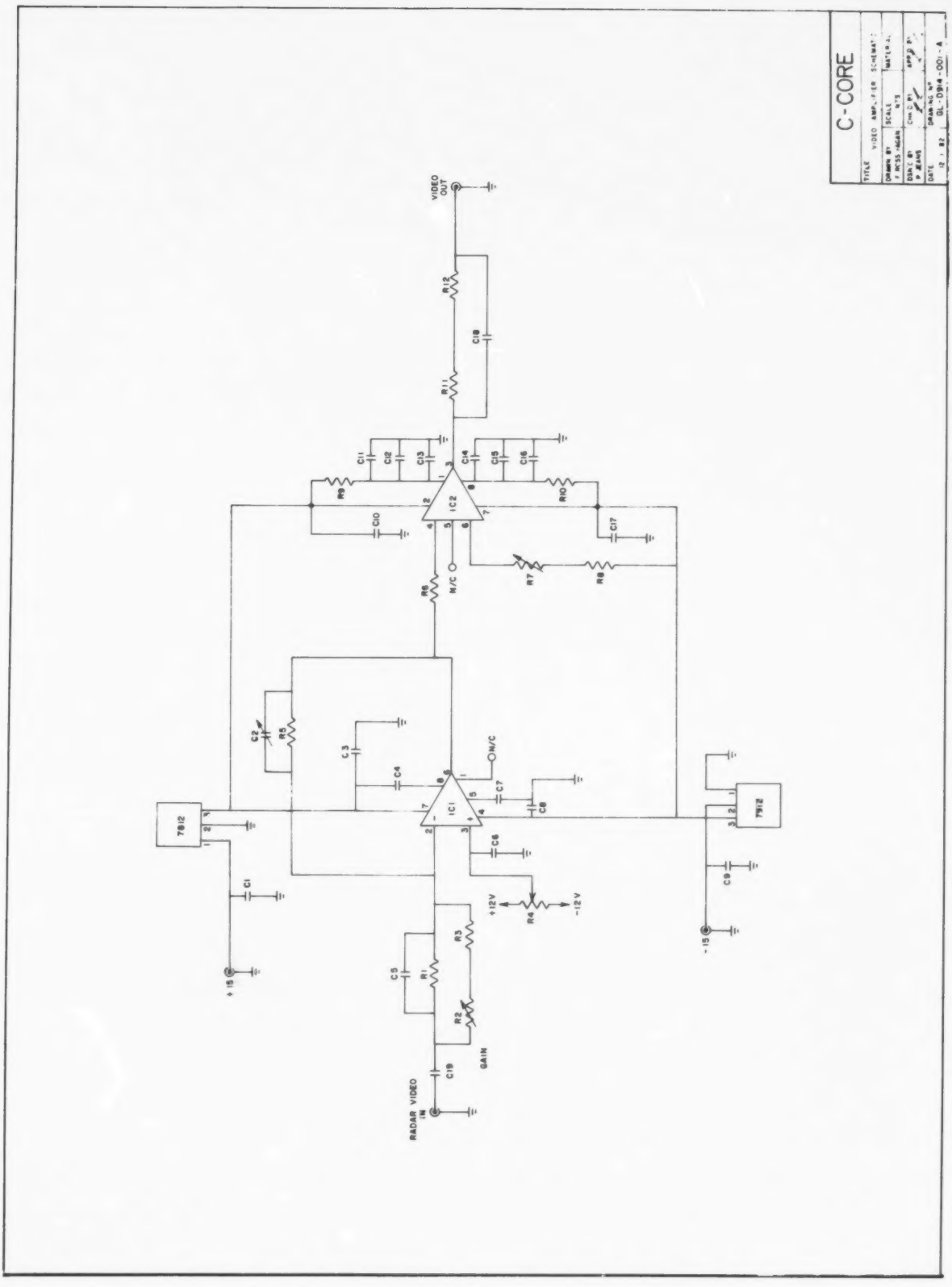
C-CORE		
POLAR - CARTESIAN CONVERTER		REV
DRAWN BY J. ROSS TAGAN	SCALE N.T.S	MATERIAL
CHK'D BY	DATE	DRAWING No.
DES'D BY	APPR'D BY	GL-D814-003-A

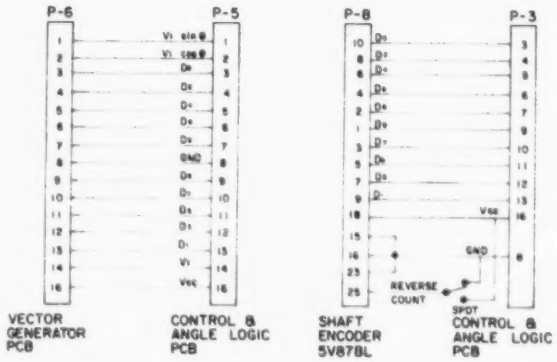


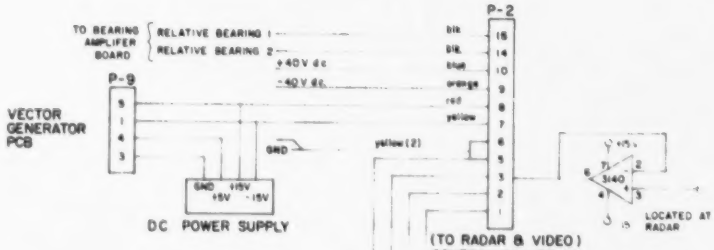
NOTES

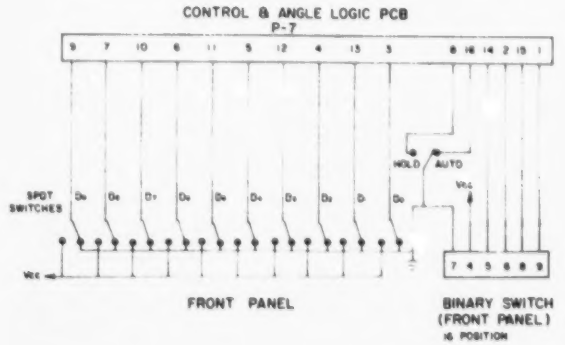
1. Complexity of circuitry required because of shaft encoder translation time debouncing and wind loading on radar antenna causing possible small reverse rotations. (Therefore, a simple counter would not be sufficent.)
2. The exception to note #1 is chip #s 14, 15, 16 which allow an option of rotating the PPI display manually.
   Using EAC (End Around Carry) on chip #s 11, 12, 13 as shown by dotted line. The above chips should be eliminated. See "Integrated Electronics" by Millman & Halkias, p. 604.
3. This chip is the maximum accuracy version (0.35°). See 8 chip 0.70° version.

C-CORE		
ABSOLUTE POSITIVE SYNCHRONIZER - SCHEMATIC		REV
DRAWN BY L. DAVIS	SCALE N.T.S.	MATERIAL
CHK'D BY	DATE	DRAWING #
DWG'D BY P. JAMES	APP'D BY	SL-DIA-000-A

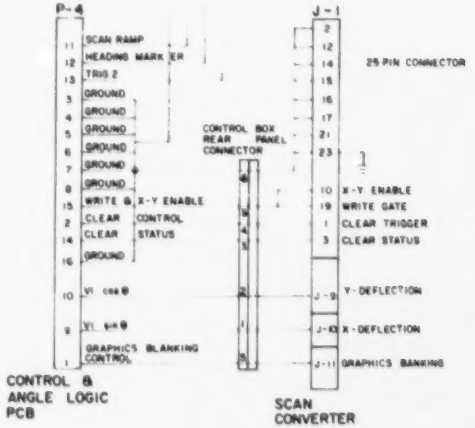

C-CORE
VIDEO OUT
R12
C18
R11
C11
C12
C13
C14
C15
C16
R9
R10
IC2
C10
C17
R6
N/C
R7
R8
C2
R5
C3
C4
IC1
C7
C8
7812
7912
C1
C6
C9
+12V
-12V
R4
R3
C5
R1
R2
GAIN
C19
RADAR VIDEO IN
+15
-15







NOTE P-3, 4, 5, 6, 7 & 8 ARE 16 PIN DIP



C-CORE	
CONTROL WIRING DIAGRAM	REV
DRAWN BY T. ROSS FRASER	SCALE N.T.S.
CHK'D BY	DATE
DSN'D BY	APP'D BY
MATERIAL	
DRAWING No.	GL-D814-002-A

APPENDIX B

MANUFACTURER'S SPECIFICATIONS

The following partial extracts reflect manufacturer's specifications for the specific product configuration options purchased by C-CORE.

The manufactuerers should be contacted for a complete list of specifications for other configurations and/or equipment options.

Extract of Specifications Published by:

BEI Electronics, Inc.
Digital Products Division
1101 McAlmont Street
Little Rock, Arkansas 72203

5V80 Series
Absolute Position Encoders

Weight, max.	18 oz.
Running torque, max.	0.3 oz.-in. @ 21°C
Moment of inertia	0.00043 oz.-in.-sec^2
Slew speed, max.	15 x 10^3 RPM
Acceleration, max.	750 x 10^3 Rad./sec.^{2}
Model 5V87	Power Requirements(1) +5.0 VDC ± 5%
Option B	892 ma

Output characteristics encoders with electronics:

Binary "1"	
Open circuit voltage:	3.8 VDC ± 0.5 VDC, open circuit
Output impedance:	160 ohms typical
Binary "0":	
Open circuit voltage:	0.4 VDC max.
Sinking current for options B, BG	14.4 ma. max.
Risetime and falltime:	200 nsec. max.
Maximum angular rate for full accuracy (5V87)	2,343 RPM

(1) Above figures calculated at no external load.

Extract of specifications published by:

Princeton Electronic Products, Inc.
P.O. Box 101, North Brunswick, N.J. 08902

PEP 500
Lithocon(R) Solid State Image Memory/Scan Converter

INPUTS

Deflection: (X and Y input)

Amplitude: ±2.5 volts for full screen deflection*+

Input Impedance: 1000 ohms*
Bandwidth: (small signal) D.C. to 1 MHz standard. D.C. to 3 MHz optional.

Step Response (full screen) 10 sec to 0.1% standard. 5 sec to 0.1% optional.

Registration Linearity:
+ 0.5% typical

WRITE AMPLIFIER

Input Amplitude: 1 volt peak-to-peak (0 volts = black)*+

Input Impedance: 75 ohms*

Bandwidth: (Equilibrium mode)
D.C. to 12 MHz

+Internally adjustable
*Standard-consult factory for additional options

OUTPUTS

Video

Composite or non-composite, specified by customer.

Bandwidth: 20 Hz to 12 MHz standard.
20 Hz to 28 MHz optional.

Amplitude: 1 volt peak-to-peak D.C. Restored. Amplitude and pedestal adjustable.

MECHANICAL

Physical Dimensions
Height: (178 mm)

Width: (432 mm)
Depth: (440 mm)

Weight (20.4 kg)

POWER REQUIREMENTS
100-130 Vac, 50/60 Hz
150 watts typical

LITHOCON TX 100 BEAM ADDRESSED MEMORY

Resolution: 2300 TV lines/diameter limiting
1350 TV_{50} lines/diameter

Writing Speed: 450 secs./scan line,
Beam Landing Mode (Equilibrium)

Linear Gray Scale: 64 levels (standard)

Gray Scale Control: 2:1 dynamic range expansion (standard)

Extract of Specifications Published by:

Analog Devices, Route 1 Industrial Park;

Digital Vector Generator
DTM 1716/17 Series

DTM1717

Digital Angular Resolution	12 bits (1 LSB = 5.3 arc-mins)
Full Scale Output	± 10V
Scaling Accuracy	0.1% FSR
Full Scale Output	± 10V
Max Slew Rate	0.5 V/ s
Full Power Output	8 kHz
Analog Input Impedance	10 k
Analog Output Impedance	100 m
Output Load	2 k
Digital Input	12 bits natural parallel binary, 1 TTL Load
Response to Digital Step (90o) (FS Analog Input)	40 s to 0.1% of final value.
Power Supplies	+15 V @ 50mA max -15 V @ 40mA max.
Dimensions	79.4 x 66.7 x 10.2 mm
Weight	3 oz (85 gm)

Specifications subject to change without notice.

APPENDIX C

SIGNAL GLOSSARY

Relative Bearing Signals (2): Generated in the antenna turning unit, the two signals carry only the angular velocity information of the antenna, and do not indicate the azimuth of the antenna relative to a known direction.

Trig: Timing pulse generated in transceiver unit simultaneously with firing of magnetron (i.e. simultaneous with transmit pulse). Used to indicate start of radar video (i.e. Range = zero nautical miles).

Scan Ramp: Generated in radar display unit. Linear rising sawtooth with sharp drop off. Voltage at any time is directly proportional to time interval between firing of magnetron (t_o) and any later time (t), such that range (in time) = $(t-t_o)/2V$ where V is the phase velocity of transmitted signal. After maximum range of interest the scan ramp drops to zero. Used to displace electron beam (of PPI) to "r", the radial coordinate of target.

Heading Marker: Located in the radar turning unit, this marker is fixed with respect to the transmission direction of the antenna, so it rotates with the antenna. It operates a reed switch, which when closed, generates the heading marker signal. Once per sweep the antenna beam passes through a known point of

reference, generating a heading marker signal, e.g. on a ship the heading marker would indicate when the antenna direction passed through the bow. For a land based operation, the heading marker might indicate true north, etc.

Clear Status: TTL signal generated from scan converter. It is high when "Clear" in progress (i.e. erasure of stored data), low otherwise.

Graphics Unblanking: Electron beam in scan converter suppressed when input is TTL = 0. TTL = 1 allows electron beam to write. Only effective in write mode.

X - Y Enable: TTL = 1 input places scan converter into x-y format, position of electron beam is determined by external x and y inputs.

Clear Control: TTL = 1 input places scan converter into "Clear" cycle, which results in erasure of stored data.

Azimuth: Digital 10 bit angle generated from optical encoder. The optical encoder is driven indirectly by the relative bearing signals of the turning unit. The bearing signals determine speed of rotation only. Azimuth by itself is an arbitrary angle. The difference between, the angle of the antenna relative to the heading direction and the heading azimuth, equals the true azimuth.

i.e. (Azimuth - Heading Azimuth) = True Azimuth.

Heading Azimuth: an arbitrary 10 bit digital angle from the optical encoder at the time the heading marker signal arrives. A constant angle to be subtracted from the output of the optical encoder to compute the antenna's true azimuth relative to the heading direction.

APPENDIX D

HARDWARE COSTS

Item	Approximate Cost (Canadian)
Bearing Amplifier Board	$ 690.00
Deflection Coil Motor	480.00
PEP 500 Solid State ($6,035 US)	
Image/Memory Scan Converter	7,240.00
Grey Level Enhancement Control	360.00
Video Circuit	120.00
Optical Encoder 5V87BL ($606 US)	730.00
DTM 1717 (Vector Generator)	